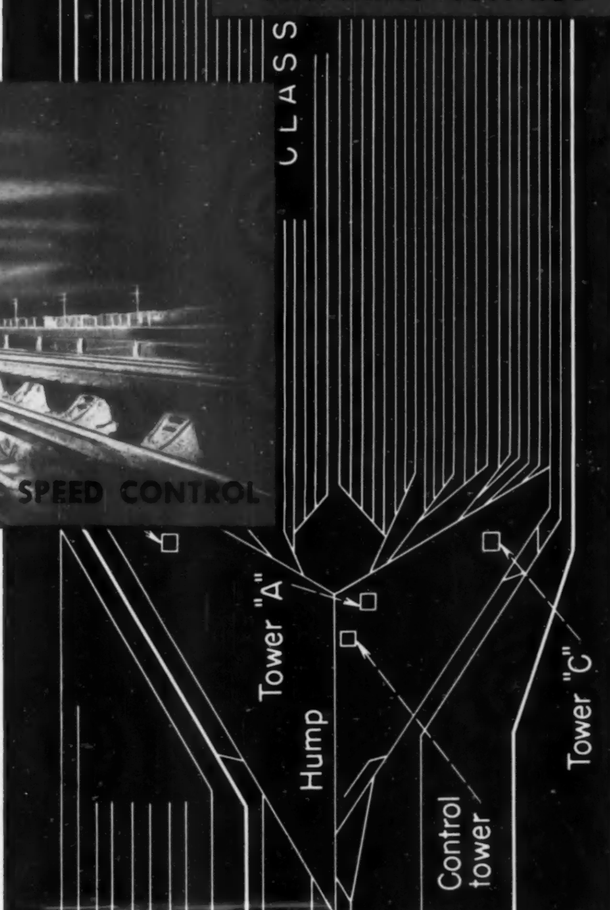
Control ENGINEERING

INSTRUMENTATION AND AUTOMATIC CONTROL SYSTEMS

A McGRAW-HILL PUBLICATION • PRICE 50 CENTS

JANUARY 1955



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Integrated computer-controlled system promises to save $1 million a year in AUTOMATIC FREIGHTYARD

SPEED CONTROL

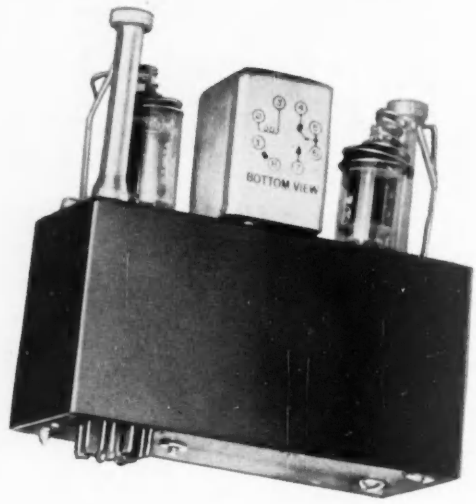
ALSO IN THIS ISSUE:

Coordinate Control with Process Development
Electronic Counting Moves into Control
Mechanical Integrators Control Torque-Speed
How Control Companies Grow

Centralized Operations Control...

Economical with Modular Design Multi-Gate®

Plug-in Tone Transmitter



Plug-in Tone Receiver

When planning a system to operate apparatus at a remote location from a central master station, it is important not only that the equipment perform as required, but also that it be easy and economical to install and service. On the first count, Hammarlund Muti-Gate equipment assures fast-acting, fail-safe operation of a practically unlimited number of control functions over a single circuit. On the second count, it's a snap to install and maintain because of its new modular construction. And that means lower operating and maintenance costs.

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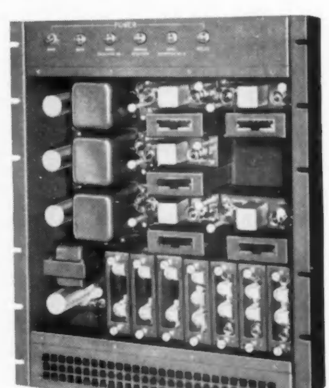
Typical Multi-Gate Receiving Terminal

This unit takes little space and is readily accessible when mounted in a standard 19" rack. Special window covers protect all relays from dust. Control of ventilation maintains conservative temperature levels throughout the equipment.



HAMMARLUND

EQUIPMENT FOR COC—CENTRALIZED OPERATIONS CONTROL

Control ENGINEERING

JANUARY 1955

INSTRUMENTATION AND AUTOMATION CONTROL SYSTEMS

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SHOPTALK FROM EDITOR TO READER

EDITORS HAVE TO BE ATHLETES

Looking into the Union Pacific's new automatic freight classification yard proved strenuous for managing editor George Boehm and assistant editor Ed Kompass. To get a buzzard's-eye view, they clambered up a 100-foot floodlight tower near the hump. The ascent was worth the strain, for Ed got some fine pictures from the top, including this one of George already part way down.

And they got an exciting story of an integrated control system that combines the engineering approaches of automatic materials handling, continuous process control, and digital and analog computer technology. Starting on page 28, you can read their account of this $250,000 system that could pay for itself in just 90 days.

"I CAN BUILD ANYTHING I DESIGN"

That's what our new assistant editor Ray Auger claims. He's busily backing up his assertion by constructing the ingenious clockwork torque amplifier that he describes on page 63. Among his other projects is a houseboat, moored near Long Beach, Long Island.

At Georgia Tech and Columbia, Ray combined engineering with courses in writing and psychology. At Georgia Tech he helped found the literary magazine "Swivet" and wrote for other campus publications. While continuing his study, he's been a successful electromechanical instrument designer with Columbia Radiation Laboratory and General Time Corp. Somehow he finds time to work on another project: a digital graphic XYZ recorder designed to plot data on neurological and psychological response rates.

DO YOU WATCH TELEVISION?

If so, keep an eye out for the new CBS film on automatic control described on page 12. It was telecast Nov. 21 in 60 cities on the network's Sunday afternoon documentary program "The Search." And it is now making the rounds in other areas. If you missed the first showing, you can still catch it when CBS repeats the series. The presentation is authentic, interesting, and to control engineers, gratifying. Far more emphatically than most of us can, it explains our work to our families and friends.


corridor to Mars?
SANTA MONICA
Flights such as this are, of course, in the future—However, we predict that when the first space flight is made, an American Gyro control system and control components will be used to assure PRECISE CONTROL.
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FEEDBACK FROM READER TO EDITOR

David Boyd Fan

To the Editor—

I especially enjoyed your article on Dave Boyd [October issue, page 11]. I have not seen his basement in probably four years. The description, however, still sounds quite familiar, and I thus fear that Dave has the usual trouble of not being able to part with equipment.

N. B. Nichols, Mgr.
Research Div.
Raytheon Mfg. Co.
Waltham, Mass.

Critic and Author

To the Editor—

In your October issue, page 35, Mr. Hochschild makes the statement: "Most metallic crystals are noncubic . . ." I wonder how he reconciled this statement with the tables of crystallographic data. Of all the common metals used for fabricating machinery, etc., only magnesium is noncubic. Out of 40 metals, including almost everything except the rare earths, 23 are cubic, 12 hexagonal, and 5 are allotropic, having at least one cubic form.

R. K. Dickey
Berkeley, Calif.

You are quite correct in pointing out that most metals are cubic, and I appreciate your correcting this error. Actually, it arose in the following way.

Though most metals are cubic, most are not simple cubic and therefore have different tensor properties (e.g., elasticity) along their different crystal axes. Conductivity was mistakenly thought to be a tensor property, but is actually a vector property and therefore does not differ along different axes of cubic crystals; that is, body-centered cubic and face-centered cubic.

You may be interested to know, however, that in many cases orientation may be detected with eddy currents, even in the cubic crystalline metals. The reason is that many processes such as rolling, which produces orientation due to working of the metal, also produce dislocations which are directionally oriented and therefore cause increased scattering of electrons in certain preferred directions. In severely worked metal, the effect may be as high as 2 per cent in conductivity. Sensitive eddy current equipment will respond to conductivity effects much smaller than this.—Richard Hochschild

Whipping Post

To the Editor—

Regarding my paper "Cost vs. Performance in Process Control Systems," which you abstracted on pages 92 and 93 of your November issue, I wish to call attention to serious typographical errors, which appeared in the ISA reprint and carried over into Control Engineering.

On page 3 of the reprint, it is erroneously stated for Case 3 that there is no isolating relay between the cut-off relay and the control board. On page 4, all of the regulator performance figures should be in terms of cycles per minute rather than cycles per second.

Page S. Buckley
Engineering Research Lab.
E. I. duPont deNemours & Co.
Wilmington, Del.

More About Cubics

To the Editor—

First, my compliments to the Control Engineering staff on a splendid start on their publication.

Second, I welcomed Mr. W. H. Gable's article, "Solving Cubics This Way is Easy," Oct., 1954, which gives a neat short-cut on a discouraging and time-consuming topic.

After giving Mr. Gable's parameters some thought, I came to the conclusion that since, for most accuracy in solution it would be desirable to have

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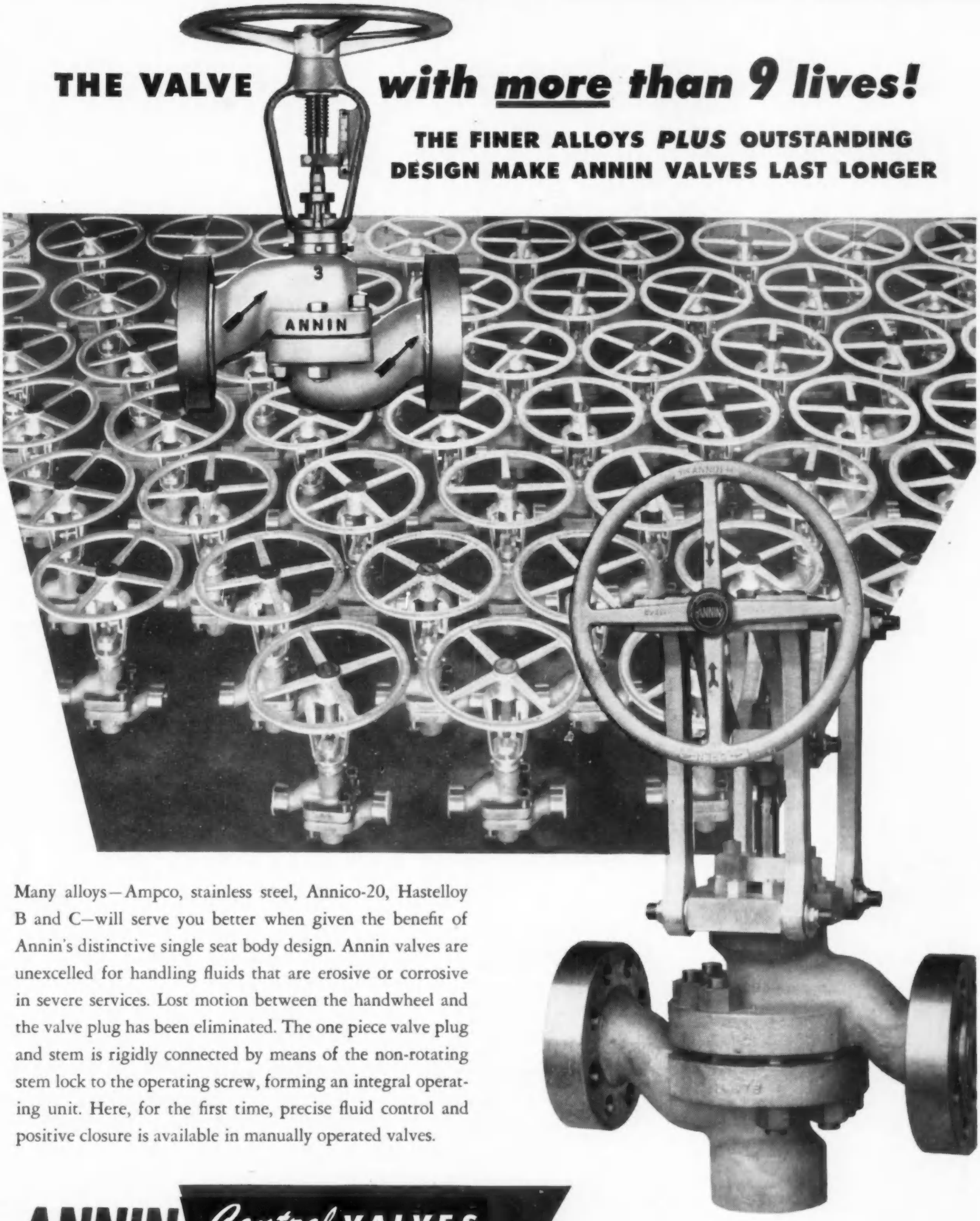
THE FINER ALLOYS *PLUS* OUTSTANDING DESIGN MAKE ANNIN VALVES LAST LONGER



Many alloys—Ampco, stainless steel, Annico-20, Hastelloy B and C—will serve you better when given the benefit of Annin's distinctive single seat body design. Annin valves are unexcelled for handling fluids that are erosive or corrosive in severe services. Lost motion between the handwheel and the valve plug has been eliminated. The one piece valve plug and stem is rigidly connected by means of the non-rotating stem lock to the operating screw, forming an integral operating unit. Here, for the first time, precise fluid control and positive closure is available in manually operated valves.

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FEEDBACK

1) a plot of relatively large scale (say 11 x 17 in.), and

2) a very fine-line curve of great accuracy, why not plot just two good curves, with great care, of the form

$$y = -x^3 - ax^2$$

one for a is positive and one for a is negative, and assigning a definite value to a, say a = 3, or

$$y = -x^3 - 3x^2$$

Then if the cubic to be solved is of the nature

$$x^3 + a'x^2 + b'x + c = 0$$

change a' to a = 3 by multiplying a' by $\frac{a}{a'} = \frac{3}{a'}$, and to obtain the linear intersections multiply b' by $\left(\frac{a}{a'}\right)^2 = \frac{9}{a'^2}$ and multiply c' by $\left(\frac{a}{a'}\right)^3 = \frac{27}{a'^3}$

Or we would simply plot the line

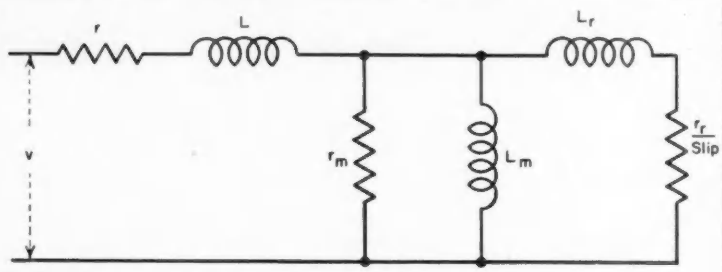
$$y = \left(\frac{a}{a'}\right)^2 b'x + \left(\frac{a}{a'}\right)^3 c' = \left(\frac{9}{a'^2}\right) b'x + \left(\frac{27}{a'^3}\right) c'$$

on top of the general plot, $y = -x^3 - ax^2 = -x^3 - 3x^2$. (This would be done very lightly just to obtain the solutions and the line would then be erased from the plot.) The values of x at the intersections would then be read off and multiplied by $\frac{a'}{a} = \frac{a'}{3}$ to obtain the desired solutions. This should simplify the plot construction and should give greater accuracy, however simplicity of use is sacrificed but certainly not severely.

Reinhold Fischer
Carbide and Carbon Chemical Co.
South Charleston, W. Va.

CAN YOU SOLVE THIS PROBLEM?

Here is the third contribution to the problem exchange we started last month. If you wish, you can sign your problems and solutions, but you don't have to. Remember, we offer cash awards to both submitters and solvers.



Equivalent circuit of one phase of two-phase induction motor

PROBLEM 3:

How to predict braking torque of dc on two-phase servomotor.

Willie Jones is using a two-phase servomotor. At one point in the control cycle he applies dc to one phase of the servomotor to act as a braking voltage. He removes the ac before doing this, naturally. Willie Jones would like to predict the effect of the dc in producing braking torque; so he remembers the equivalent circuit for the two-phase induction motor which he studied in college. He remembers that no restriction was placed upon line frequency in deriving this equivalent circuit and therefore feels that all he has to do is substitute the dc voltage on the motor phase and calculate rotor torque. To his chagrin, he finds that L_m is a complete short on the secondary winding when the applied voltage is direct, and that apparently no power will be transmitted to the rotor. Hence, no rotor torque can be generated, and yet Willie knows that rotor torque will be generated due to eddy current drag. Can you explain away his dilemma? Frankly, I couldn't.

This Bailey Armortube* Cable can save you time and money

With this new material especially designed for pneumatic connecting lines you can make better instrument and control installations in less time and at less cost. Here's why:

Simple — Standard ARMORTUBE* cable is stocked in three convenient sizes: bundles of four, eight, or twelve ¼ inch O.D. aluminum alloy or copper tubes. Other sizes are available on special order. It's a ready-made, fully protected piping material for transmitting pneumatic signals between measuring units, instruments, and control units.

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P-30

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INSTRUMENTS AND CONTROLS

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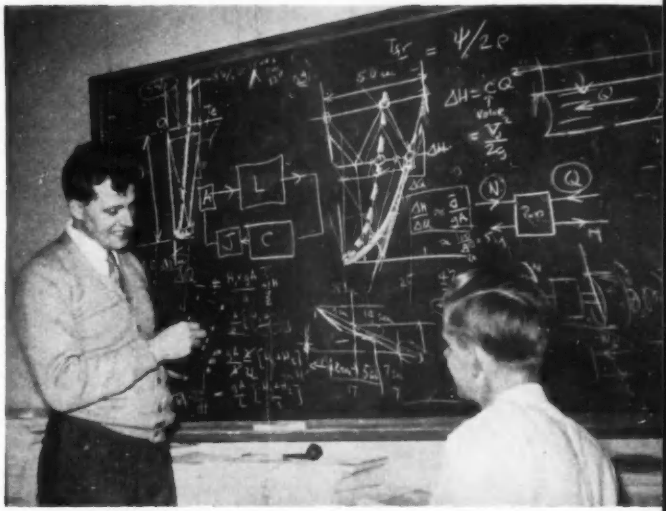
A CONTROL PERSONALITY

HANK PAYNTER applies statistical analysis

While attending Peekskill (N. Y.) High School, Henry M. Paynter found an error in Albert Einstein's work. He corresponded with Dr. Einstein, who confirmed the error found by the young mathematician. Through succeeding years, Hank's technical interest has shifted from mathematics to hydrology and fluid mechanics, to hydroelectric control, and in the last four years, to broad applications of automatic control. Quick appraisal of his apparently shifting course indicates a neglect of his first love, mathematics, until we recognize that a basic mathematical field—statistical analysis—links his technical interests.

Hank's efforts to apply statistical analysis to engineering and industrial problems and to develop improved hand and machine computational techniques were well underway when he got his ScD in Civil Engineering at MIT in June, 1951. Since then he has become a busy man. Two days a week he teaches engineering analysis, systems design, and automatic control as an Assistant Professor in the MIT Mechanical Engineering Dept. He apportions the other days and evenings among:

- ▶ Writing three books tentatively entitled: 1) Graphical Solution of Engineering Transients, 2) Analysis and Design of Engineering Systems, and 3) Unsteady Flow in Pipes and Channels.
- ▶ His duties as president of Pi-Square Engineering, an organization consulting in the application of electronic analog computers.
- ▶ A second consulting venture, this one with Dr. Harl P. Aldrich, Jr., in the study of thermal transients in the ground.
- ▶ Preparing technical society papers and a series of tutorial articles for CONTROL ENGINEERING.
- ▶ His wife and four children; his colonial (1795) house in Reading, Mass.



Hank implements his excellent class lectures with blackboard graphics in colored chalk. After filling every square inch of the blackboard, he starts all over again without removing any of the preceding material. A Paynter chalktalk should be sketched on a continuous belt with high-speed access.

"He's not unorthodox— he's an engineer," says his wife

Hank met his wife, Gayliss, while a summer employee at Coulee Dam in Washington. Married in 1944, they have two boys and two girls.

After some years of observation, his wife believes, "engineers are a breed unto themselves. Unorthodox? Hank is always popping with new ideas and plans. He works hard . . . long, and, for the most part, enthusiastically. To me his outstanding trait is tireless interest in his work.

"It isn't that he doesn't enjoy other things. He enjoys everything (except ballroom dancing?)."

Tootling a recorder, he plays Pied Piper

When the Paynters took their first vacation last summer, they chose Boothbay Harbor, Me. Until then, Hank had spent his summers teaching surveying at Camp Technology, East Machias, Me. There he charmed the children of the staff with tunes on his recorder.

Here is an example of the new breed of scientist-engineer. Thirty-one years young, gifted with creative ability, trained in theory, experienced in practice, concerned over bringing theory and practice together, he is a leader in our field.

During a break Romine studies the script. Then back in action, Wiener purrs his philosophy to an unnumbered audience

Control Engineers Star on Network TV

CBS show confronts American public with concept and accomplishment of automatic control. Don Campbell heads MIT cast explaining new technological era

Forrester holds forth on Whirlwind's exceptional computational capabilities

On Nov. 21 a group of control engineers competed directly with professional football games, family outings, and other relaxation appropriate to a late fall Sunday afternoon. As entertainers the engineers came out well; as evangelists, perhaps even better.

The occasion was the first showing of the Columbia Broadcasting System's new half-hour television documentary on automatic control. The film, one of CBS's weekly "The Search" series, was shown on 60 network outlets. Since its debut, it has been featured by many additional stations. And in the future it will probably be rerun. By the time the film has made its final rounds, most of America will have had a chance to grasp the significance of control.

Good entertainment though it is, the show is utterly free from theatrical whoopla. Two men saw to that: producer and network director of public affairs Irv Gitlin and writer John Pfeiffer, who majored in physics at Yale.

For acting talent they turned to MIT. Prof. Don Campbell, head of the Servomechanisms Lab, played the leading role, ably supported by Prof. Norbert Wiener, father of cybernetics; Prof. Gordon Brown, head of electrical engineering; Jay Forrester, director of the digital computer lab; and others.

The film starts by showing a giant hydraulic press in action. This machine, Campbell explains to narrator Charles Romine, is awe-inspiring, but it simply substitutes for human muscle. He then introduces the concept of machines that substitute for routine thinking.

In subsequent scenes Wiener explains the instincts of Felix the feedback moth that always turns toward the brightest light. Brown expounds feedback, illustrating his remarks with a gyrocompass mounted on a model ship. Forrester puts his Whirlwind computer through its paces. And Jim McDonough of the servo lab displays tape control of a milling machine. Moving off campus briefly, Romine interviews Claude Shannon of Bell

Labs, who shows how his famous mechanical mouse solves maze problems.

Anticipating his audience's reaction, Romine keeps asking whether these remarkable machines think. Each time the answer is "no," although Wiener's is carefully qualified.

Although Pfeiffer, after painstakingly interviewing the several participants, wrote a complete script, it was never intended to be followed exactly. Instead, each actor studied the questions Romine would ask him and then indicated roughly the ground his answers would cover. This procedure allowed the engineers to speak naturally, yet kept them from wandering from the main track of the show.

The result was an effective and dramatic presentation of a family of unfamiliar and inherently difficult concepts. Judging from initial response, hundreds of thousands of televiewers are getting a fresh respect for and understanding of automatic control.

CBS plans to lend the film to professional groups. For further information, write directly to Irv Gitlin at CBS, 488 Madison Ave., New York 22, N. Y.

RCA Antitrust Suit Buffets Entire Electronics Industry

Electronics manufacturers, from the smallest to the largest, felt the shock as Justice Department antitrusters let fly at the Radio Corp. of America.

RCA is the biggest seller of most radio and television products–including, through NBC, programs. But the Justice Department found no quarrel at this time with the company's dominant sales position. Rather, the lawyers were scrutinizing RCA's control of some 10,000 patents in the radio-television field.

The antitrust suit, filed in New York, charges that since 1932 RCA has deliberately monopolized radio-television research, patents and patent rights, and the issuance and exchange of licenses to other manufacturers.

Government attorneys say they want to create conditions in which RCA's competitors can compete at every level from research to end products. But no one knows, if the courts decide RCA has violated antitrust laws, just how far the government will go in demanding relief. Conceivably, it could make RCA turn over to the public hundreds of patents, as General Electric was forced to do last year after losing a monopoly suit on incandescent lamps.

The complaint lists several other companies as RCA's co-conspirators: General Electric; American Tel&Tel and its subsidiaries Western Electric and Bell Labs; and Westinghouse Electric. This is the same group sued in 1930 for conspiring to monopolize radio manufacture and the sending of messages by wire and radio.

The 1930 case was settled after two years by a consent decree. GE and Westinghouse gave up stock control of RCA, and along with AT&T they agreed that all patent licenses exchanged with RCA were no longer to give RCA exclusive rights to license to other manufacturers.

Ten years later, in 1942, trustbuster Thurman Arnold tried to vacate this settlement, but lost his case in Federal District Court. The current suit takes up where Arnold left off. Its main target is RCA's so-called "package licensing" policy. When a radio-television manufacturer licenses an RCA patent, he gets rights to any of the company's 10,000 patents that apply to his product. Royalties run from $\frac{1}{4}$ to 4 per cent of manufacturers' selling price, which includes cabinets, packing materials, and other non-electronic adjuncts.

The government objects that RCA makes a manufacturer license, in effect, all 10,000 patents, even though he may use but two or three. Furthermore, the Justice Department charges, anyone trying to "invent around RCA" never really knows which RCA patent he is bucking. RCA has started about 250 infringement suits, but the antitrust attorneys claim nevertheless that not a single RCA patent has been held valid by the courts. RCA, they say, can keep a competitor eternally tied up in litigation simply by charging that he has infringed one or another of the 10,000 patents.

Important Moves By Key People

▶ **Norman Lieblich** is now vice-president of Kieley & Mueller, Inc. He had been chief applications engineer for the control-valves and steam-specialties firm, and more recently general sales manager.

▶ **Dr. Wendell A. Horning,** theoretical nuclear physicist, has joined the Guided Missile Division of The Ramo-Wooldridge Corp. His background includes six years at the General Electric-AEC Hanford works and two years as instructor at the University of Rangoon, Burma.

Lieblich is now Kieley & Mueller v-p

Horning: Burma to Hanford to LA

Elliott heads R-F in Canada

► **Ralph A. Rockwell** has been appointed chief engineer for the Valve Division of Minneapolis-Honeywell Regulator Corp. A veteran with 30 years' experience in the field, he will continue to advise the division's sales and engineering departments, coordinating the design, application, and production of industrial valves.

► **George A. Elliott**, English-born electrical engineer, is vice-president and general manager of Robertshaw-Fulton Controls (Canada) Ltd., the newly formed Toronto subsidiary of the U. S. instrument and control firm.

► Librascope, Inc., has made **Richard E. Hastings** general manager of its subsidiary Minnesota Electronics Corp. He will have charge of manufacturing decision elements—building-block components for military and industrial controls and computers.

COMPUTER NOTES

New Memory is Inside-Out

Combine the best inherent features of magnetic tape and rotating drum and you get a memory storage that is both large and easy to get at. This is just what Clevite-Brush Development Co. engineers have done. Their invention is a magnetic drum turned inside-out and festooned with tape.

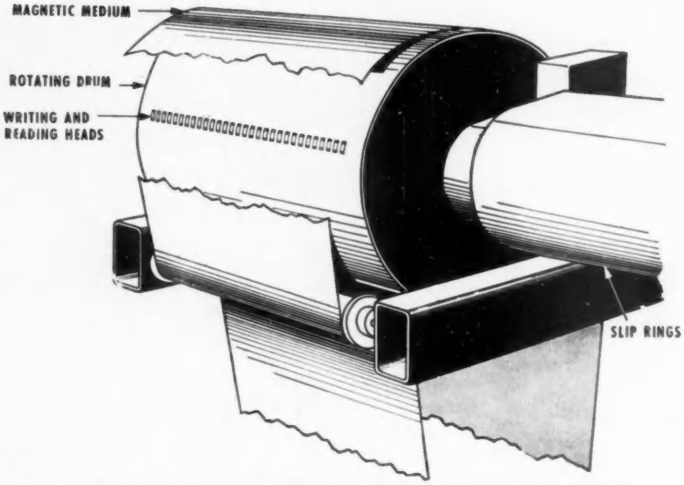
Instead of whirling a drum past stationary heads, as is usually done, they have put 128 reading and recording heads inside the drum. Draped over the outside is a broad belt of magnetic tape. The tape is stationary, while the drum spins 20 times per sec.

This arrangement makes it possible to scan 200,000 bits of information (magnetized on that part of the tape that touches the drum surface) 20 times per sec. If you want to explore information stored on some other part of the tape, you turn on the tape drive until you reach the proper "page."

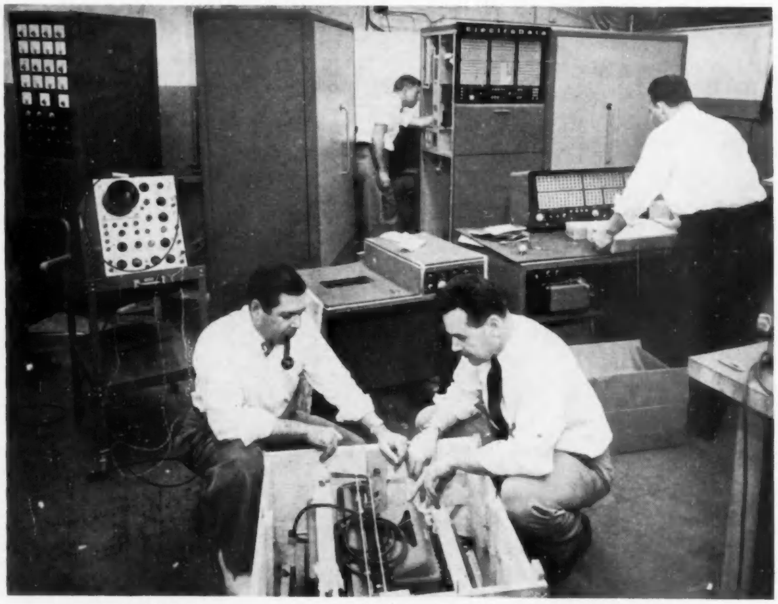
The whole memory, about the size of a three-drawer file, has as much capacity as 200 conventional drum recorders. An interesting note: the spin of the drum maintains a thin air cushion on its surface. The tape, floating on this cushion, doesn't wear. Nor need the designer worry much about keeping close tolerance between the reading-and-recording heads and the magnetized surface.

Purdue Starts New Center

With the delivery of an ElectroData computer, Purdue University began a multi-purpose computer center. Students will be able to learn how to build computers and make them work. And the equipment in the center will



Tapedrum combines speed of magnetic drums with capacity of tape memory



ElectroData's 1½-ton computer starts the ball rolling at Purdue's new center

help out with management and research problems of other university departments as well as midwest industrial organizations.

Automatic Flight Ahead

Started: a $1 million project to design comprehensive digital-computer control for high-speed military aircraft and guided missiles. Westinghouse Electric and Ramo-Wooldridge are getting together to devise a miniature digital airborne computer that will make completely automatic all flight and tactical operations.

Looking at the project broadly F. W. Godsey, manager of Westinghouse's Baltimore divisions, and Dr. Dean Wooldridge, president of R-W stated jointly: "It is not commonly appreciated that recent advances in digital computing have been so rapid that it now appears practicable to design into lightweight airborne equipment most of the same high-speed, highly accurate computing and data-handling capability that characterizes the electronic equipment now being applied to scientific, business, and industrial tasks.

"This means taking today's bulky computers off the ground, where they have been confined until now, and converting them into compact and light-weight packages for aircraft, where they will automatically control simultaneous functions such as flight, navigation, engine and fire control in the higher-speed aircraft and guided missiles of the future."

AROUND THE BUSINESS LOOP

▶ **Ketay Instrument Corp.** and **Norden Laboratories Corp.** announced plans to merge and become the **Norden-Ketay Corp.** Holders of Norden common stock are being offered one share of Ketay for every four of Norden. Both companies will continue independent manufacturing operations without major personnel changes. Morris Ketay, founder and president of Ketay, is to be president of the new firm, while Norden president Paul Adams is to be chairman of the executive committee and vice-president.

The new combination represents the merging of common interests. Norden, successor to the maker of the famous bombsight, develops and manufactures electromechanical instruments, systems, and computers. Ketay is the nation's largest producer of precision servos, synchros, and resolvers. And both have recently branched out into the nuclear field. Norden is working on instrumentation and controls for commercial atomic energy. A recently formed Ketay subsidiary, Nuclear Science and Engineering Corp., offers research and other engineering services to industry.

Ketay has also bought stock control of the Vari-ohm Corp., thereby adding precision potentiometers to its line of control components.

▶ In a simpler corporate move, **Minneapolis-Honeywell Regulator Co.** bought up **Doelcam Corp.** of Boston, manufacturer of precision instruments and controls for aircraft and industry. Under its president and founder John J. Wilson, Doelcam will operate as a Honeywell division.

▶ "I wonder if I could use a computer." Answers to this often-expressed thought will come from **Canning, Sisson, and Associates,** a new Los Angeles firm. The new company has been set up to "assist industrial managements and government agencies in utilizing electronic computers and other automatic data-handling equipment." It is headed by Richard G. Canning, formerly data system engineer with the University of California at Los Angeles, and Roger L. Sisson, who has resigned as manager of the customer service department, electronics division, National Cash Register (once, Computer Research).

▶ **Texas Instruments, Inc.,** just purchased 6 acres of land in Houston. On this tract will be built a new plant and general headquarters for Texas Instruments' wholly-owned subsidiary Houston Technical Laboratories, maker of gravity meters, geophysical instruments, and optical components for the petroleum industry.

▶ In other expansion moves, **Helipot Corp.** opened a Canadian plant in Toronto. And **Magnetic Research Corp.** increased its elbow room 300 per cent by transferring to roomier quarters in El Segundo, Calif. In the smog-frantic Los Angeles area, **Librascope** has occupied a new 55,000 sq ft Glendale plant. In addition to being smog-proofed by air-conditioning, the building is earthquake-resistant.

▶ Two familiar names have been changed. **Avien-Knickerbocker,** known for fuel-gaging systems and other aeronautical instruments, is now **Avien, Inc.** The Special Products Department of **Beckman Instruments, Inc.,** is to be called the Industrial Instrument Department, reflecting emphasis on automatic instrumentation.

Science Foundation Surveys U. S. Industrial Research

The National Science Foundation is getting early returns of a questionnaire on industrial scientific research and development in the U.S. This questionnaire, sent to 12,000 firms, is just the first phase of an intensive nationwide survey. Later, canvassers

Magnetic Research Corp. found 300 per cent more elbow room, while Helipot branched out into Canada

How Indiana-designed Permanent Magnets

made a loud-speaker lighter .. a nuclear resonance research unit more powerful!

Here are two case histories showing interesting and somewhat unusual applications of Indiana Permanent Magnets . . one tells the story of a tiny 1/10 ounce magnet, the other the story of a massive ½ ton magnet.

Each application called for creative and imaginative thinking . . the same kind of original engineering and design thinking that is an important part of every Indiana Permanent Magnet.

Because Indiana Steel Products Company believes so strongly in the vital importance of creative and originative magnet design, it maintains the world's largest engineering staff devoted solely to the design and application of permanent magnets.

This specialized service is available to original equipment manufacturers. Indiana engineers, with more than 45 years experience in designing permanent magnets for some 40,000 applications, will welcome the opportunity to work with you in the development of *your* permanent magnet designs. Write for detailed information and a copy of *Engineering Design Manual 4-P-1*.

1/10-OUNCE PERMANENT MAGNET . . This headphone set, which includes a loud-speaker only 13/16" in diameter, is used with secretarial transcribing machines, group-hearing systems, for hotel and hospital radios, in beauty salons, dental offices, broadcasting studios, airports, etc.

The headset had to be light, which called for an exceptionally light permanent magnet of high energy. Level or sound quality could not be sacrificed. The manufacturer working with Indiana design engineers used Hyflux Alnico V. Result: Indiana Permanent Magnets that weigh only 1/10 ounce.

½-TON PERMANENT MAGNET . . Here is one of the world's largest permanent magnet assemblies. Used in nuclear resonance research, it contains over 1,000 pounds of Indiana Hyflux Alnico V, and produces a magnetic field of 6,750 gausses in the air gap.

It provides an extremely stable field. Critical controls, necessary with electromagnets, are not required. No heat is generated to effect critical conditions . . . and being a permanent magnet, its power won't fail during an experiment. Indiana engineers designed this giant assembly to customer's exact requirements.

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World's Largest Manufacturer of Permanent Magnets

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Write for your subscription to Applied Magnetics . . a bi-monthly publication carrying helpful, practical information about permanent magnets and their application to industrial and consumer products. Please write on company letterhead.

will interview representatives of 200 selected large corporations.

Among the 12,000 who got the questionnaire were 4,000 companies that employ at least 1,000 persons. The remainder were chosen as a cross-section of the nation's 3,000,000 industrial firms.

In soliciting the information, Dr. Allen T. Waterman, former Yale physicist who now heads the foundation, pointed out: "The findings should be valuable to companies in planning and appraising their own research programs, besides contributing greatly to the formulation of national policies for the strengthening of scientific research."

The survey is aimed at finding out how much money is spent on research development by companies of various sizes and in various fields; where the money comes from; and how much companies pay for research done by consultants, colleges and research institutes.

Also, the foundation will attempt to analyze the research history of selected companies to reconstruct a gross pattern of industrial research over the last 20 or 30 years.

Putting all this information together, the analysts expect to come up with a reasonable estimate of the money and technical manpower the U. S. will need to keep up its standard of research and development.

"And after two complete—excuse me—molds are—oops, sorry—assembled the pouring—pardon me—ladle is actuated on this conveyor where—excuse me...."

Tiny Gyro-Compass Designed For Beachhead Operations

Naval assault craft and amphibious vehicles are getting a new navigational aid. It's a gyro-compass about the size of your fist and weighing only 9 lb. Yet its performance rivals that of present-day master gyros that stand 4 ft high and weigh 900 lb.

This remarkable new instrument was developed jointly by the Navy's Bureau of Ships and the Sperry Gyroscope Co. and is designated Mark 22. Now each landing craft, no matter how small, can maneuver precisely on its own.

Mark 22 passed rugged Navy tests. It stayed accurate through sharp abrupt turns of speeding boats and the buffeting of beaching operations and rough seas.

Because the new instrument fits on a shelf near the steering station, it needs no steering repeater system. And it is so inherently simple that untrained personnel can handle it.

TECHNICAL SOCIETIES

IRE Elects Officers

The 40,000 members of the Institute of Radio Engineers have chosen as their 1955 president John D. Ryder, dean of the Michigan State College School of Engineering. He will take over from William R. Hewlett, vice-president of Hewlett-Packard Co.

In recognition of IRE's international character, Prof. Franz Tank of the Swiss Institute of Technology will be vice-president, succeeding Maurice J. H. Ponte, director of Compagnie Generale de Telegraphie Sans Fils. New directors for the next two years are John F. Byrne, director of engineering at the Communications and Electronics Division of Motorola, Inc.; and Prof. Ernst Weber, head of electrical engineering at Brooklyn Poly.

Dean Ryder, who joined the Michigan State faculty last July, has been teaching in the Midwest since 1941.

ASTE Sets Up Awards

The American Society of Tool Engineers has established four gold-medal awards to be presented for the first time at the annual meeting in Los Angeles, March 14-18. They are: the ASTE Gold Medal, for service through publications and papers; the ASTE Progress Award, for advances in manufacturing and production techniques; the Joseph A. Siegal Memorial Award, for contributions to the welfare of the ASTE; and the ASTE Engineering Citation, for unusual skill in developing tool engineering principles.

Committee to Speed Patent Processing

Dr. Vannevar Bush heads the new Advisory Committee on Application of Machines to Patent Office Operations. The group aims to increase the speed and efficiency of patent searches and thus cut the time between application for and granting of patents.

Commented Sec. of Commerce Sinclair Weeks: "If high-speed electronic devices can be used to replace time-consuming manual sorting and searching of reference material, the result could be a tremendous boon to inventive progress."

One of a series telling how the producing companies of General Precision Equipment Corporation are contributing to America's progress.

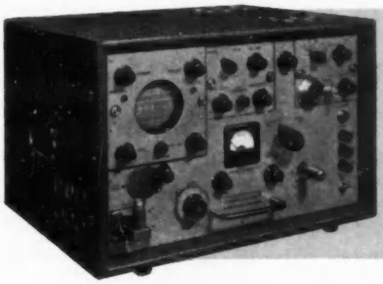
precision technology

GPE Coordinated Precision Technology is the basic GPE operating policy which inter-relates the research, development and manufacturing facilities, techniques and capabilities of the producing companies of General Precision Equipment Corporation. Thus each company's specialization in its particular areas of competence is supplemented by the application of the resources of the other companies, wherever relevant. A diversified line of advanced precision equipment of superior design and performance has resulted from this application of the newest and most advanced techniques possessed among the companies in every technical capacity.

e.g. in ELECTRONICS

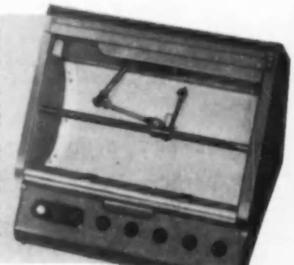
Ten of the GPE Producing Companies work in this important field. These companies were "born in electronics" and pioneered in its development before the word was coined. Their work covers every phase of electronics and GPE coordination relates each new electronic problem to the specialized knowledge and experience which is most valuable. This secures the optimum solution for the customer with minimum expenditure of time and money.

GPE Producing Companies have been responsible for the research, development and manufacture of a wide range of electronic precision components, equipment and systems, including Theatre Sound Systems, Sonar Equipments, Flight Simulators, Industrial Control Systems, Analogue Computers, Digital Computers and Components, Industrial and Studio Television, Navigation Systems—both airborne and marine. GPE systems, in most instances, are advanced concepts, often employing components specifically developed for the purpose by one of the GPE companies. Of the great number, two are shown.



Kearfott X-band Test Set, frequency range 8,500 to 10,000 MC; a unique all-purpose portable radar test set, comprising a power monitor, spectrum analyzer, wavemeter and signal generator which supplies an accurately calibrated signal of known level with variable amplitude and pulse-width combinations. Also provides FM, square wave and CW output.

Librascope X-Y Plotter and Recorder; automatically displays data derived from punch cards, mechanical or electronic computers or sensing elements; features rapid graphic 2-axis display with provision for 10-fold scale expansion and zero suppression. Used in aero-dynamic and electronic research, as well as in mass data reduction systems for business and industry.



Most advanced technological products which utilize electronics also call for other advanced technological skills. Though space allows only for an outline of GPE's work in electronics, both the capacities chart on the facing page and most of the products mentioned above serve to suggest the broad coordination of technical capacities in all fields which exists as a result of GPE Coordinated Precision Technology.

Address inquiries to: **GENERAL PRECISION EQUIPMENT CORPORATION**
92 GOLD STREET, NEW YORK 38, NEW YORK

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THE STRONG ELECTRIC CORPORATION—TOLEDO

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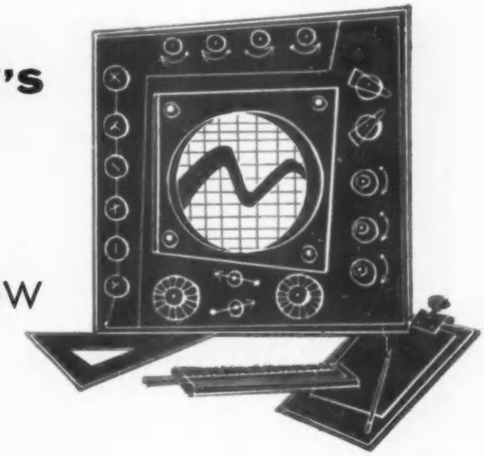
INDUSTRY'S PULSE



How Control Companies Grow

As we reported in "Industry's Pulse" for October, Wall Street is enthusiastic about instrumentation and automatic control. Security analysts foresee enormous growth in this field. We got to wondering how control companies grow. So we scrutinized the histories and plans of those that have already expanded considerably and we cross-examined some of their top executives.

Here are some outstanding examples. Maybe their organization patterns will help you decide where to buy instruments and control equipment—and also how to invest, where to work, or how to model your own aspirations.

Some Straddle The Field

Minneapolis-Honeywell Regulator is still growing, but it is the prime example of a mature and completely diversified control company. Among them, its various divisions and subsidiaries can design almost any control system and build it with Honeywell components. To continue straddling the field, the company depends on its own research and development. And it adjusts its dynamic balance by adding subsidiaries.

General Precision Equipment is another well-diversified company, made up mostly of established companies that understand their own production and marketing and do their own development. A superimposed link is General Precision Laboratory, which supplements development facilities of the other semiautonomous members of the corporation and plans to handle much basic development work for the Armed Services. GPE has for many years been active also in a field unrelated to control—namely, movie projectors.

Others Concentrate On a Major Section

Unlike Minneapolis-Honeywell and GPE, **Ketay Manufacturing** concentrates on government contracts and a specific field of manufacture: such components as servos, synchros, resolvers, and precision potentiometers. Its amalgamation with Norden, now in the works, is expansion but not diversification. Ketay's philosophy stems from the assertion that "government developments of today are successful commercial developments of tomorrow." And for brand new companies, president Morris Ketay has this advice. Start by making components, not systems. Com-

ELECTROSYN

NEW rugged, reliable system for remote indication and control of pressure and temperature

The NORWOOD CONTROLS ElectroSyn is unique in its ruggedness, its reliability and the minimum maintenance it requires. Without complex electronic circuits, it provides an exceptionally high output signal, electrically transmitted, which makes possible accurate remote readings of pressure and temperature. It is suitable for use with multi-point indicating or recording systems. When desired, an explosion-proof construction (rupture-proof to twice line pressures) is available.

Accurate to within ±¼% of rating at any point within range . . . linear within ±¼% of rating . . . unaffected by lateral and longitudinal vibration, or by line voltage change . . . ranges available: to 5,000 psi, −50°F to 1200°F.

ElectroSyn has been especially engineered for pipe line and chemical processing applications where sturdy construction and permanent accuracy are essential.

NC NORWOOD CONTROLS

Controls Division

CONTROL ENGINEERING CORPORATION

931 Washington Street • Norwood, Mass.

Complete technical information will be supplied upon request

ponents can be made and sold so rapidly that limited capital can be turned over as often as a dozen times a year. It's harder to get fat on elaborate systems that take much longer to design and put together.

New Firms Are Military-Minded

Getting around to some of the brand new firms, **Litton Industries** started with a pot of gold from Lehman Brothers. With no initial financing problems, it is buying up a welter of organizations and welding them into a somewhat specialized electronic-control and data-handling empire. Litton is largely committed to military work but is alert for industrial possibilities.

Ramo-Wooldridge likewise leaped into business with strong backing — from Thompson Products. Unlike Litton, R-W has a management team of top scientists and engineers. It has booked $10 million worth of military development contracts and is reaching, at its own expense, for industrial inventory and production control jobs.

Leach Corp. also had an "angel." It bought up four established component manufacturers who were especially strong on production. And at the top it installed a virile organization of designers and businessmen. Look to Leach for sound mechanical designs of power, voltage, and speed regulators, to be sold impartially to industry and the military.

Landlord Will Swallow Tenants

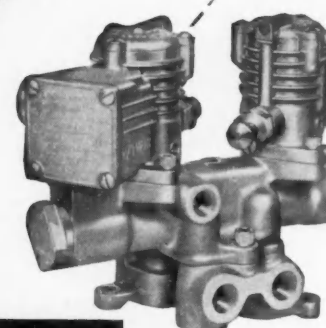
Another vigorous young California firm plans a "Control Park" — a sort of industrial estate with rental space for many of its key component suppliers. As the landlord grows, he hopes to buy up his tenants. Meanwhile, he will have minimized his communication and shipping problems.

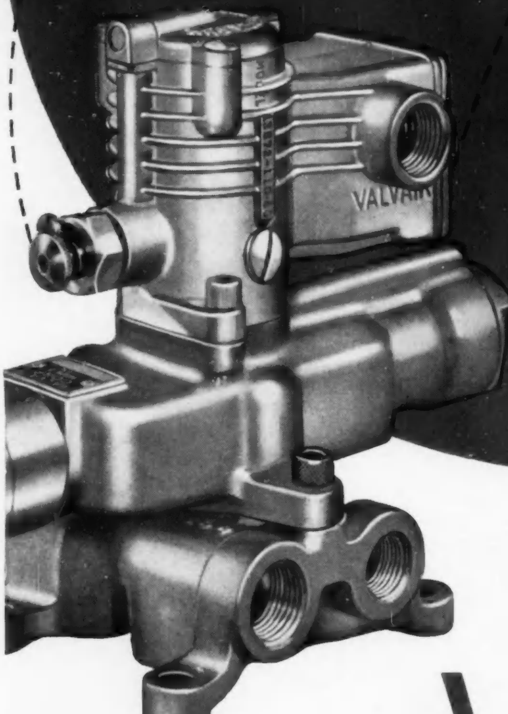
At least two major companies in the field have turned their talents inwards. They have turned loose their control systems men on their own production lines. Aside from improving the companies' manufacturing, this scheme will fill a reservoir with additional practical experience, which will be available to customers who buy systems or consulting services.

Several of the men we interviewed expressed this thought: It's getting harder to grow by buying smaller companies. The reason is that few sound firms are now for sale. Empire building has already drained the control kingdom market.

DOUBLE

solenoid
pilot operated
control valve





SPEED KING

Valvair is proud to announce another advancement in the field of automation—The Double Solenoid Speed King Control Valve, designed especially for both the Original Equipment Manufacturer and the End User. This development proves that, more than ever before, Valvair is the name to keep in mind when you order solenoid-operated valves.

Features: Momentary electrical contact—35 to 200 psi pneumatics with internal pilot supply—35 to 150 psi hydraulics with internal pilot supply—Vacuum—300 psi pneumatics and hydraulics using external or remote pilot supply—4-way body—foot or manifold mounting—basic 3/8" and 3/4" sizes.

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Control ENGINEERING
JANUARY 1955

Education Is Our Limit

Education is the key variable in the management problems incident to the growing industrial application of instrumentation and automatic control. The rate of exploiting automatic controls is directly proportional to the rate at which people are trained to understand, design, and service them.

We hear that employees displaced by automatic control will be educated to intellectually superior jobs. This supposes that they are eager to upgrade themselves. But even though they recognize the need to develop higher technical ability, will they allocate spare time to education? Or will they choose to spend precious free hours watching TV? We refuse to presume that all men are farseeing and ambitious.

Training has to be made inexpensive, attractive, and alive. Present it as an opportunity for improved living – not as a tedious duty. Offer training through our technical societies. One of the main reasons they exist is to educate their members. At present the societies build training sessions around educational centers. This is too limited an outlook. It leaves large areas unserved and dodges the responsibility of coordination at a national level.

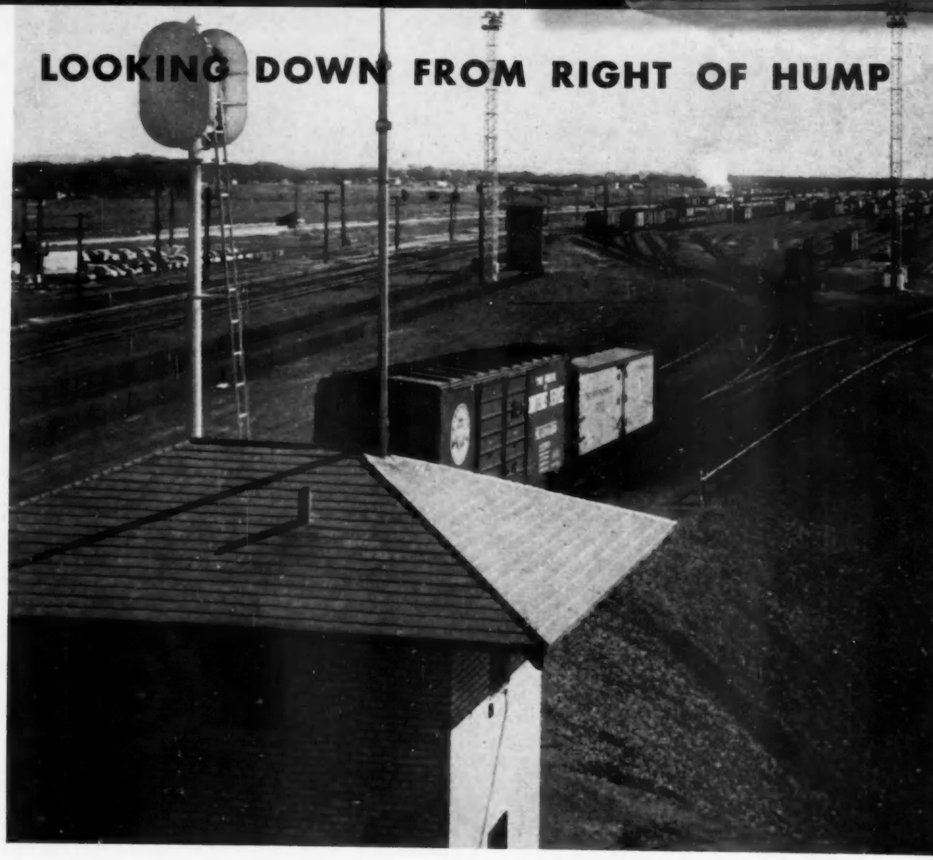
We propose four basic steps. First, the societies should coordinate their educational activities nationally. Second, they must prepare course outlines sufficiently complete to guide instructors in places remote from educational centers. Third, they must make available training aids, like those developed by the Armed Services. Helpful examples would be Doc Mason's "Control Demonstration Panel," simple analog and digital computers, or even plywood working models. But they all cost money. So the fourth step is to provide aid – equipment or money to buy it.

We commend ISA on leading the way with the movie "Principles of Automatic Control" and with the "Industrial Training Course Outline." ISA is the natural bridge from mechanic to instrument man to instrument engineer. ASME, AIEE, and IRE have complementary professional divisions for the control systems engineer. And IRE's Professional Group on Electronic Computers has an instruction program.

It's time the societies jointly organized a curriculum that steps progressively from instrument mechanic training to instruction for the advanced control engineer. We think industry will gladly aid such a plan well thought-out by the technical societies working in unison.

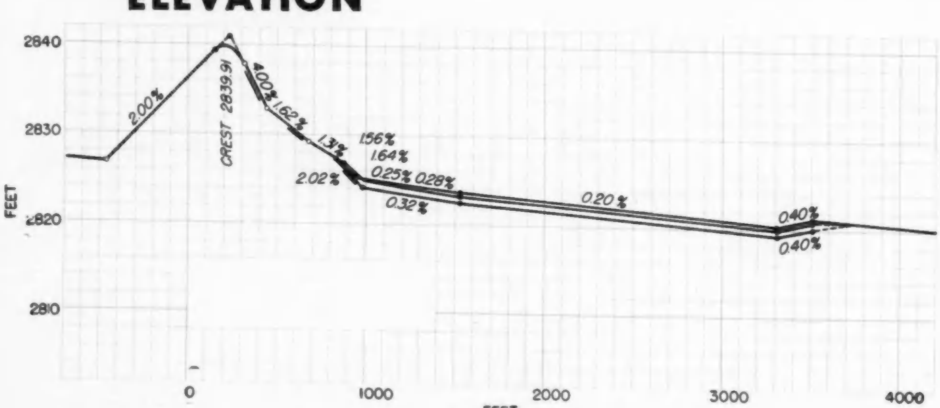
THE EDITORS

3 Views of THE YARD



DIAGRAM

ELEVATION



"Union Pacific Railroad Photo."

American railroads pay $100,000,000 a year for freight damaged—much of it in yards where trains are assembled. This new computer-controlled system promises to slash the bill. It controls the rolling speed of cars so that they couple gently. Besides, it memorizes the destinations of a long list of freight cars and automatically switches each to its proper outbound train.

Automatic Freightyard Shuffles Cars Quickly Yet Gently

A 100-CAR FREIGHT, EASTBOUND FROM PORTLAND, ORE., waits on a track in the Union Pacific's yard at North Platte, Neb. Beside it stands a similar train from Los Angeles. Both have cars destined for Chicago, Kansas City, Atlanta, and New York.

Here at the center of the United States the trains will be reclassified. They will be dismembered, and the cars will be collated into new trains with destinations more specific than just "east."

On a long journey a freight car may pass through several such classification yards. If its route is coast-to-coast, it may start on any train headed in the right general direction. But as it approaches its destination, it must be aimed more exactly.

In most classification yards, switch engines shuffle the cars. But the big ones, such as the Union Pacific's North Platte yard, depend on "humping." A train that is being reclassified is backed slowly over a rise, called in railroad parlance the "hump." Just before a car hits the downgrade, a switchman pulls the coupling pin. Then the car, cut loose from the train, rolls freely to one of the tracks that fan out from the hump. Each of these tracks is the storage for a new train.

Ideally, a hump yard slopes so that each car coasts down at a constant velocity. Unfortunately, cars differ. Some will accelerate so that they reach the final track at high speed and couple with a

THE DESIGNERS AND . . . .

DAVE BETTISON, veteran signal engineer, started railroading on the Louisville & Nashville as a teen-ager in 1911. Joined UP as a draftsman 37 years ago. He concentrated on the digital analog, "Hailstorm."

RON BERTI, Nebraska-born, got his EE from Iowa State College in 1935. Went to work for UP as an electrician 16 years ago. He conceived the basic speed-and-switching-control system.

PERRY SEAY, Alabaman, joined Reeves in 1947, soon after getting his MEE from the University of Texas. He applied his knowledge of analog computers to the finicky problem of speed control.

resounding crash, smashing or shifting their loads. Others decelerate and stall midway, so that a switch engine has to pursue them and nudge them along. A strong tailwind, for example, will give wings to even the most sluggish car.

So that switchmen can exercise some control over the velocity of a car leaving the hump, many classification yards have installed "retarders," steel brakes along the rails, that grip the flanges of the wheels (see FIG. 8 on page 34). A switchman perched in a control tower operates the retarders remotely. In a few seconds after the car leaves the hump and before it reaches the retarder, he must judge whether it is a "hard roller" or an "easy roller" or something in between. And, according to his judgment, he must apply just the right amount of braking pressure so that the car will arrive at the end of the track rolling about 2 mph.

This requires inhumanly precise judgment. A car takes two or three minutes or more to reach its target car. In addition, cars pass over the hump in such rapid succession that six or eight of them usually are in transit while the switchman is retarding the next car. He has no chance to observe how violently a car is coupling until at least half a dozen more cars have passed him.

An experienced switchman gets used to the characteristics of the yard, even one with 42 tracks. But the friction characteristics of cars vary, and wind velocity also is a major factor. The most skillful switchman, therefore, has constant trouble with some cars that don't quite reach the end of the track and others that couple hard enough to damage freight.

The switchman has another task. Working from a list of the cars of the train passing over the hump, he must assign each car to its proper outbound track. Thus, in the case of the North Platte yard, he must set as many as seven switches for each car.

WHO GETS THE PATENT $$$$$$?

According to Union Pacific policy, Berti and Bettison will retain patent rights to their parts of the system. The UP can use the patents free of charge, but the two engineers will get all royalties from other railroads that license their patents. Reeves, of course, has applied for patents on Seay's contributions to the system.

Automatic System Conceived

Clearly, the conventional retarder yard demands too much human judgment. Several years ago Ronald Berti, an assistant electrical engineer on Union Pacific's staff, started toying with the idea of an automatic retarder yard. With signal engineer David C. Bettison and the Reeves Instrument Corp., he attacked the problem.

The Union Pacific expected no miracles. So far as its top engineers were concerned, the project was an elaborate study. But the investigation has paid off far more than anyone would have dared to predict.

Of the yard's 42 tracks, eight now incorporate the

system devised by Berti, Bettison, and Perry Seay of Reeves. Seay, working with Reeves project engineer John Eckenbach, contributed a computing control system that measures the rolling characteristics of each car, calculates the correct exit speed from the retarder, and then controls the retarder. The computer includes an electronic analog of the yard itself. The rolling characteristics of each track were measured by sending a special test car over the hump. The object is to release each car from the final retarder so that it couples at about 2 mph.

Seay likens his problem to one in ballistics. The speed with which the car leaves the retarder is analogous to muzzle velocity. If a car goes to a track which already contains 50 cars, it may have only a few hundred feet to travel. On an empty track, it may roll as much as two-thirds of a mile. This factor is analogous to range. Other analogous parameters include wind and height through which the car (or projectile) falls.

Rust was one variable peculiar to freight cars. Often the trucks do not pivot freely. If a car comes out of a curve with a skewed truck, the flanges squeal and grind on the rails, acting like brakes. To solve this problem, Berti installed a flange oiler and also clump-clumps—steel bumps welded opposite each other on the rails. When the wheels hit the clump-clump, the truck straightens. The term clump-clump phonetically describes the thudding sound of the wheels passing over the bumps.

To complement Seay's computer, Berti and Bettison designed a switching system and built it in the basement of Union Pacific's Omaha headquarters. They call their brainchild "Hailstorm"—a name descriptive of the clatter made by the glass and steel marbles that tumble through its maze of tubing.

Hailstorm is an electromechanical digital memory combined with a control system that operates the yard switches. The present model can remember track assignments of as many as 50 cars. But it can be expanded to distribute any number of cars among any number of tracks.

Analogous to each car passing through the yard is a coded group of marbles that cascades through Hailstorm, staying one switch ahead of the actual car. The control sets each switch just as the car enters the preceding switch. Thus several cars can coast through the network at the same time, and they can be spaced as closely as with the present system.

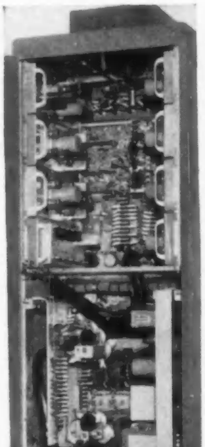
Details of both the speed and switching control systems are described separately below.

Two months of trial operation have proved that the automatic freight classification yard works as it should. But will it pay off? With no improvements on the prototype model, Union Pacific engineers estimate that the system will reduce freight damage by 80 per cent—which would amount to about $800,000 per year for the North Platte yard. Yet to equip the entire 42-track yard to handle 120-car trains would cost only an estimated $250,000.

....THE SYSTEMS THEY DESIGNED

SPEED CONTROL

As a car rolls down the hump into a retarder yard, the forces acting on the car consist of gravity due to track slope, friction, and wind. The acceleration of the car over a sample section of track where the slope is precisely known, is used as a measure of these forces. The acceleration resulting from track slope is subtracted from the total acceleration to give the net effect of friction and wind acting on the car. This latter component is assumed to be constant for the remainder of the travel of the

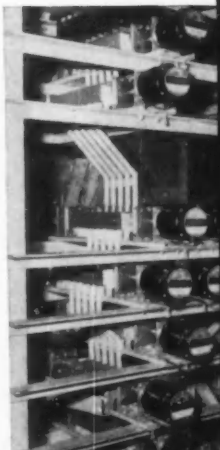


Special-purpose version of Reac computes car friction, controls speed. FIG. 4

SWITCHING CONTROL

The equipment for automatic switching is a unique memory (for storing code symbols representative of the routing for the successive cars). It has gravity operated, free rolling balls instead of relay storage banks or pulse sensing equipment.

It uses combinations of glass and steel balls in a binary code. Each code combination represents the track destination for a particular car to be classified. Each code group includes also a steel pilot ball to identify the arrival of the code group at selected



In homemade "Hailstorm," marbles simulate yard, control switching. FIG. 5.

car through the length of the classification yard.

This value of acceleration, along with the slope of the track after the retarder, is used to compute the desired exit speed of the car from the retarder. The entrance speed of the car into the retarder is determined by the time required for the car to traverse the sample section of track just before the retarder. Knowing the entrance speed and the desired exit speed of the car from the retarder, a servo system is used to operate the retarder and reduce the speed of the car from the entrance speed to the required exit speed.

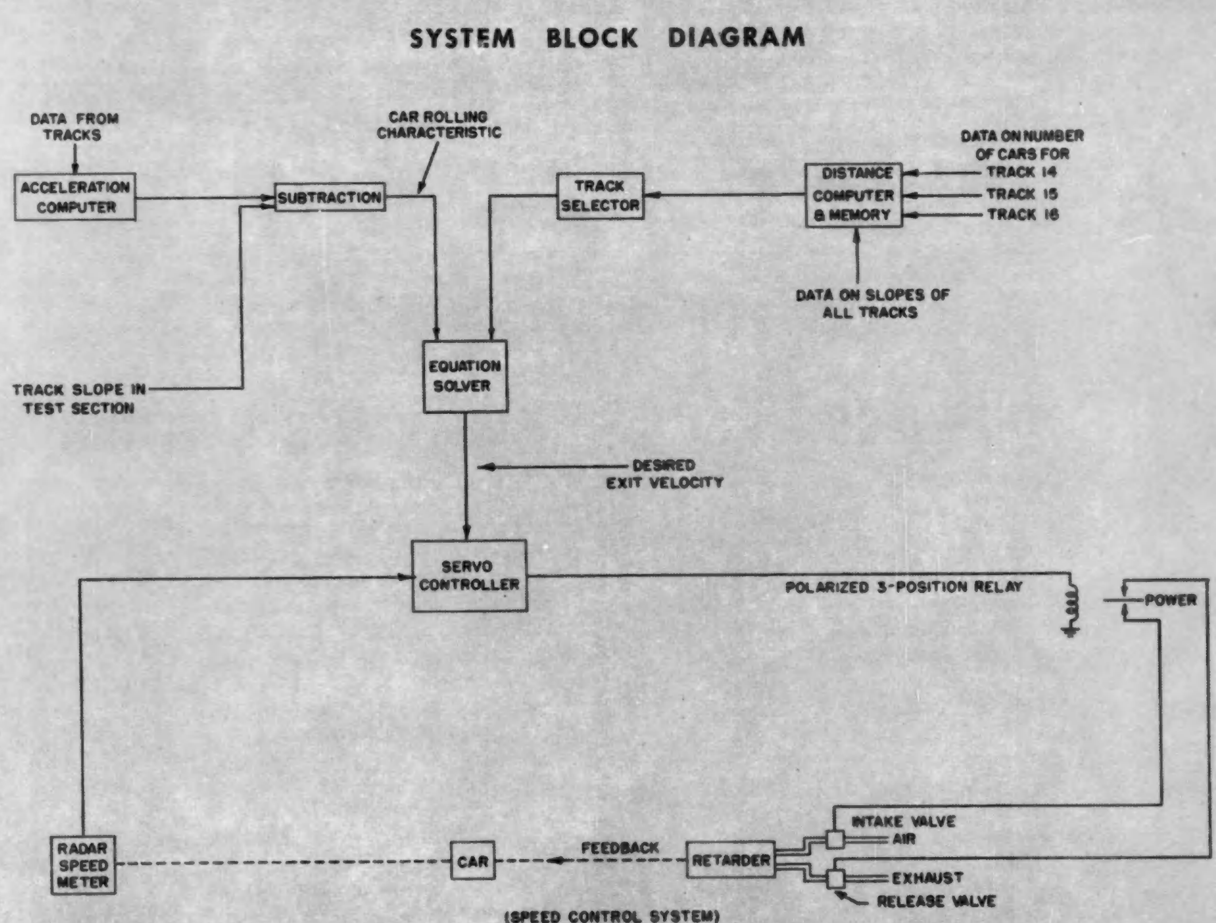
The speed of the car, while it is within the retarder, is measured by a radar speed meter. The measured speed is continuously compared with the computed speed as the car passes through the retarder and any deviation between the two is used to actuate a relay for controlling the three-way pneumatic valve on the retarder.

The equations upon which the operation of the control system is based are the simple equations of motion involving distance, time, acceleration, and velocity. The actual equations used are as follows:

$$D = V_E t + \tfrac{1}{2}at^2 \qquad (1)$$

$$t = \frac{V_T - V_E}{a} \qquad (2)$$

From these equations, it is possible to determine the required exit velocity of the car from the retarder. By substituting Equation 2 into Equation 1, distance from the retarder to the coupling point may be



Note particularly the car distance memory. Each track is divided into sections, and each new car reduces the target distance and the height through which the cars must fall. FIG. 6

positions in the machine. The number of balls in code group is always equal to the maximum number of switches which any given car must traverse in order to reach a given track, plus the pilot ball. Where the number of switches to be traversed is less than maximum the extra ball element locations are occupied by glass balls which function simply as spacers.

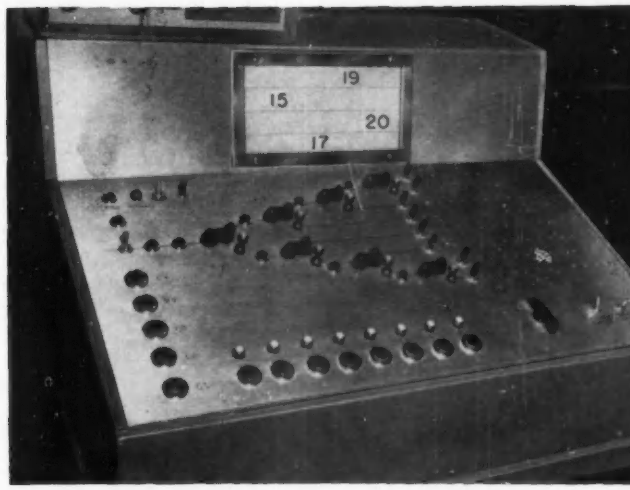
The system provides for setting up in code any number of code groups within the capacity of the device. The final installations will have a capacity at least equal to the largest number of cars that would be classified from a single train.

A lighted panel (Figure 9) indicates the track destinations of the next few cars to be classified. In the prototype four visible storages are provided, but the final installation will have five.

As the first car starts down the hump under the control of the first code-group of balls, the end ball in the group controls the direction in which the first switch is thrown. It is then discarded into the hopper at the base of the apparatus. A steel ball will throw a track switch one direction; a glass ball the other.

When the car reaches the approach section of the first switch, the code group (with the exception of the ball which has operated the first switch) cascades to the next level of the apparatus, either to the left or to the right in accordance with the track switch which it controls in the yard. Again, the end ball throws the second switch, depending upon whether the ball is steel or glass. In this way, track circuits carry the code groups progressively through the apparatus in timed relation to the progress of each car. The switch is thrown automatically, and immediately ahead of the car.

Provision is also made in the system for the cancellation of one or more code groups without replacement; insertion of one or more code groups as required; or the cancellation and substitution of one or more code groups for other groups without interfering in any way with succeeding code groups that have already been selected and stored. These functions are performed upon the code groups while they are at any of the storage positions indicated on the visible lighted panel. This is very important in the practicable handling of an automatic switching system in classification yards having full train storage.



Control panel for Union Pacific's automatic switching system. Eight tracks, those numbered 14 through 21 in the retarder yard, are controlled by the "Hailstorm." FIG. 9

Referring to Figure 10, it will be seen that the classification yard as indicated may have eight tracks, receiving cars for any one of these tracks from a single oncoming track. Seven switches are employed in this particular lay-out, the switches being numbered S1-8 through S7-8.

Figure 2 illustrates the North Platte classification

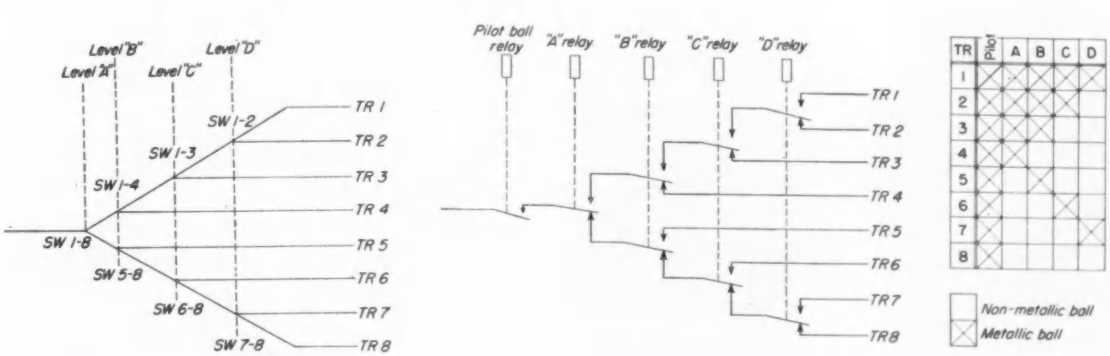


Diagram shows the switching levels in an eight-track group, as well as the decoding relay-tree for the indicator lamps and the binary code. FIG. 10

expressed in terms of the exit velocity and the acceleration acting upon the car while in transit. The equation is as follows:

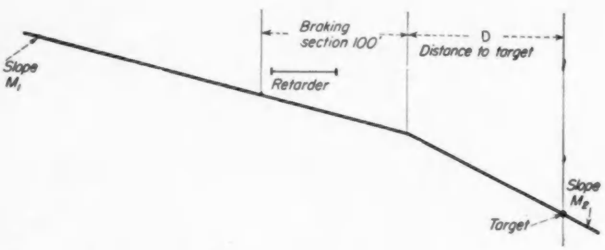
$$D = \frac{V_T^2 - V_E^2}{2a} \quad (3)$$

The acceleration, a, is made up of two components. One results from the friction and wind acting on the car and the other from the slope of the track along which the car is rolling. This may be expressed by the following equation.

$$a = M_2 g - F_R g \quad (4)$$

By substituting into Equation 3, the exit velocity is:

$$V_E^2 = V_T^2 - 2gD(M_2 - F_R) \quad (5$$



Slope and timing diagram for the Reeves friction-measuring and speed-control system. FIG. 7

Union Pacific Railroad Photo.

A three-way valve controls this pneumatic retarder to grip the car wheels and brake the car. The light-colored box at left background (just beyond the car) is the radar speed meter that monitors speed of the cars in the retarder. FIG. 8

NOMENCLATURE

- g acceleration due to gravity, 32 ft per sec²
- D distance to target from exit of breaking section
- M slope
- F_R friction and windage coefficient
- a acceleration
- V_E desired velocity at exit of breaking section
- V_T velocity at coupling point

All of the quantities are known except the coefficient of friction and windage, F_R. This is determined by measuring the acceleration of the car over the section of track prior to the entrance of the car into the retarder. This acceleration is then combined with the slope of the track within the test section to give the coefficient of friction. Thus,

$$F_R = M_1 - \frac{a}{g} \quad (6)$$

where M_1 is the track slope preceding the entry into the brake section.

Figure 6 is a block diagram of the retarder control system. An elevation view of a typical section of track is shown in Figure 7. The retarder is near the end of a section of track with a constant slope.

The precise characteristics of the individual tracks following the retarder are stored in the distance computer and memory of Figure 6. These characteristics were determined using a test car built especially for the purpose. Its rolling characteristics were measured very precisely in a series of tests at the North Platte yard. The car was rolled over sections of track to be investigated and its precise acceleration was determined. From this, the known rolling characteristics of the car were subtracted. The computed characteristics therefore included friction resulting from curvature and other track irregularities as well as the track slope.

These track characteristics are stored on banks of relays for use as required by the computer. As the car approaches the retarder, a track selector is used in the computer for selecting the proper set of constants for a particular computation depending upon the track onto which the car is to be switched. A signal for each car that passes through the test section is transmitted to the appropriate track memory, thus setting up the varying distance to the last car on each track.

The equation solver is an electrical analog computer of the Reac type. It solves Equation (5) for V_E within about one second after the car rolls over the test section prior to the retarder. Its output

yard which has 42 tracks. Classification yards of this type follow the familiar relay tree pattern where the number of switch functions required to reach any given terminus is always n-1, where n is the number of termini.

In a yard where each track can always be subdivided by switching into two tracks, the number of tracks available with p switching levels in 2_p. Thus a 42-track yard as illustrated, theoretically could be provided with six switching levels (which in fact could accommodate 64 tracks). But practical consideration of track curvature does not always allow continued subdivision of a particular switching lead, and as can be seen in Figure 2, some tracks run directly to the main body of the classification yard from as early as the fourth or fifth switching level. The yard illustrated in Figure 2, therefore, has seven switching levels thus requiring in the code make-up seven elements, plus the pilot element.

Figure 10 illustrates the code consist for the eight track yard. Since non-metallic code elements produce no electrical reaction in the system, it may seem at first thought that they are superfluous. Their presence is essential, however, as spacing elements between different code groups. Figure 11 illustrates the mechanical system for the eight track prototype with four visible storage units.

This electro-mechanical switching system divides basically into the following components:

▶ **Return hopper—magnetic separator—storage.**

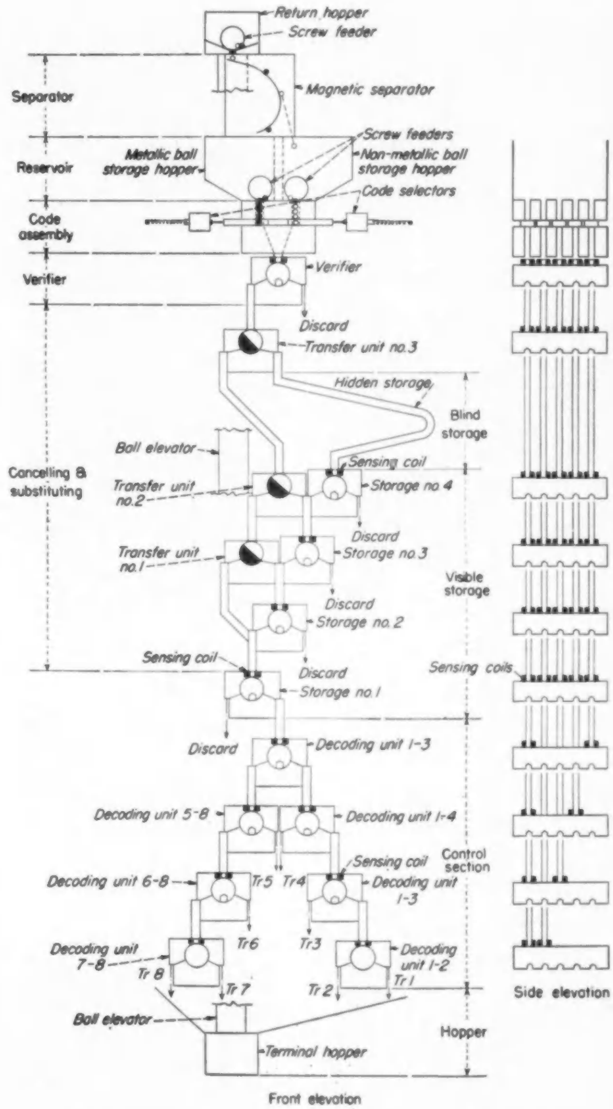
The code elements consisting of a mixture of glass and steel balls are placed in the return hopper by means of the return conveyor system. At the bottom of the return hopper a worm screw feeds the balls singly to a permanent-magnet-type magnetic separator. The magnetic separator consists of two strips of silicon steel with a side view configuration as indicated in Figure 11. The two strips are separated by an air gap approximately ½ ball diameter, and are magnetized by small permanent horseshoe magnets attached to them. The steel balls follow the separator into the steel ball hopper, while the glass balls follow a tangent pattern into the other.

Each storage hopper has a worm-screw feeder which progresses the balls over a series of short tubes spaced as indicated in side elevation of Figure 11. Each of these short intermediate storage tubes has a capacity of five or six balls. The feeders can feed additional balls into these tubes fast enough to keep up with codes being assembled.

▶ **Code assembly unit.**

The codes are assembled in parallel tubes, in this instance five tubes comprising a pilot ball tube and tubes A, B, C, and D. Tubes A, B, C, and D are related respectively to switch levels A, B, C, and D of Figure 10.

When a switchman makes a track selection by pressing a button, shuttles select the proper grouping of steel and glass balls, as per the code of Figure 10.



Front and side elevations of the "Hailstorm," which was built by Union Pacific's engineers in the basement of their Omaha headquarters. The transfer units inject a new code group for any car in visible storage without disturbing the switching code for any other car. FIG 11

▶ **Verifier-unit.**

To make certain the switchman gets the right combination for the button that has been pushed, the code group is sent to a verifier, which indicates on the panel the track which corresponds to the code combination actually present in the verifier.

is in the form of a dc voltage directly proportional to desired exit velocity. The solution is completed as the car enters the retarder and the necessary braking begins almost immediately. While the car is traveling through the retarder, its speed is monitored by a radar speed meter of a type similar to that used by traffic officers in detecting excessive speeds of motor vehicles. The speed meter delivers a dc voltage proportional to car speed. This voltage and the voltage from the equation solver are combined in the servo controller, which then regulates the speed of the car within the retarder.

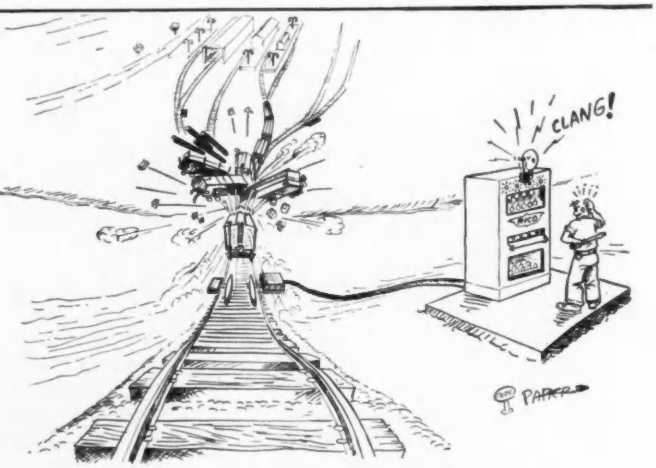
Servo Retards Cars Smoothly

The actual braking is accomplished by steel beams that rub on the sides of the car's wheels. They are mounted along the sides of each track and extend for a distance of about two car lengths. Two braking beams are used in conjunction with each rail so that forces are exerted on both sides of each wheel and forces that would tend to derail the car are counterbalanced. The beams are actuated by air cylinders distributed along the length of the retarder and controlled by pressures up to about 100 psi. Pressure in the cylinders is controlled by a solenoid-operated valve, which is actuated by the relay on the output of the servo controller.

The design of the servo controller is such that just the right amount of braking is applied to reduce the car speed to the desired exit value after it has traversed very nearly the full distance within the retarder. This is highly desirable. Even though lateral forces exerted by the beams are counterbalanced, excessive braking will lift a light car completely off the rails. In addition to this, distributing the braking over the full length of the retarder minimizes wear in the portion of the retarder where braking first begins.

In order to appreciate fully the accuracy requirements for the measuring and computing sections of the automatic retarder, a typical case may be considered. For a car rolling at an average rate of 6 ft per sec, or about 4 mph, 400 sec are required to traverse a distance of 2,400 ft. This is a typical distance to roll on an empty track. An error of .03 percent gravity, or about .01 ft per sec squared, in either the measurement of acceleration or the computation of friction coefficient will result in an error in coupling speed of 4 ft per sec.

This also illustrates the extreme handicap under which a switchman is working when he does not have the aid of precise measuring and computing equipment. When it is considered that he observes the rolling characteristic of a car for a distance of only about 100 ft before it enters the retarder, his need for unusual skill is even more apparent. At this point, a car traveling at an average speed of 16 ft per sec, a typical case, will require only about 6 sec to traverse the distance. A decelerating factor of .01 ft per sec squared will cause the car to change in speed by only .06 ft per sec. Thus, in order for the switchman to sense accurately a car's rolling rolling characteristic, he must be able to observe variations in car speed of small fractions of a foot per second. A good switchman has a right to be proud of his hard-learned professional skill.



" I'D BETTER USE A 10K RESISTOR NEXT TIME "

After the job was done, Reeves engineers took time out to kid each other. FIG. 13

The verifier unit not only checks code combinations for the proper selection of balls, but also senses the presence of a ball in each channel. In the event of either an improper code, or an incomplete code, the unit automatically rejects it and apprises the switchman by means of a warning buzzer. The system thereupon refuses to accept any additional codes until he acknowledges the error, and restores the verifier to operation.

▶ **Storage units.**

If the correct code has been composed, it then goes through long blind storage tubes to a series of cascading storage units each one of which corresponds to a line on the visible storage panel. The first storage unit selected goes to the lower cascade unit and is automatically held there with the number corresponding to the code of that group appearing on the lowermost line of the panel. The next code selected goes to the cascade unit immediately above; and additional codes subsequently stack up in the upper cascading units of the visible storage group, with numbers appearing on the corresponding lines of the visible storage panel for the subsequent code selections. The subsequent code groups pass through the verifier and pile up in the blind storage tubes.

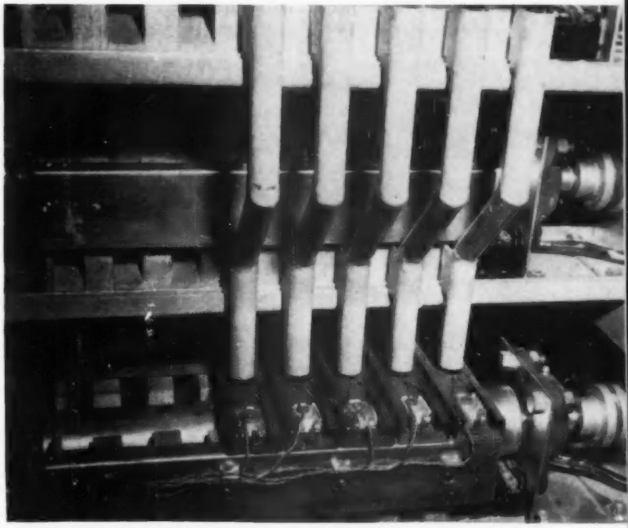
When the blind storage section has reached its capacity, a light and buzzer notify the switchman. He acknowledges and silences the buzzer by pressing a button, but the light stays on until enough codes have left the blind storage section to make room for additional storage. Simultaneously with the full-storage indication, the code selector buttons are automatically de-energized, making it impossible to store additional codes.

The switchman can cancel any of the track destinations that appear on the lighted panel. When he cancels a code, he has a choice. He can either substitute another code. Or he can move all subsequent codes one position ahead in the order. This provision is necessary, because the switchman works from a typed list of cars when he fills the storage. Thus he can correct typographical errors at the last minute.

▶ **Decoding units.**

As the code groups cascade, their presence at any given station is sensed by the pilot ball which is steel, and which detunes a high-frequency resonant circuit having a coil that surrounds the ball at each station (Figure 12.) Similar sensing coils in each of the tubes A, B, C, and D at each station determine whether a steel or glass ball is present.

One important difference between the functioning of the relays controlling the indicator panel and relays controlling the track switches may be noted by referring to Figure 10. It may be seen that in the case of the indicator panel all of the contacts at each level are controlled by a single relay, and thus only one relay is required regardless of the number of switches associated with that level. In the case of the track switches, however, a separate sensing coil (and relay) is associated with each track switch and this is a desirable arrangement.



Closeup of the sensing elements of the "Hailstorm." The presence of steel balls increases the inductance of the coils, detuning the high-frequency resonant circuits. Glass balls have no effect on the inductance. FIG. 12

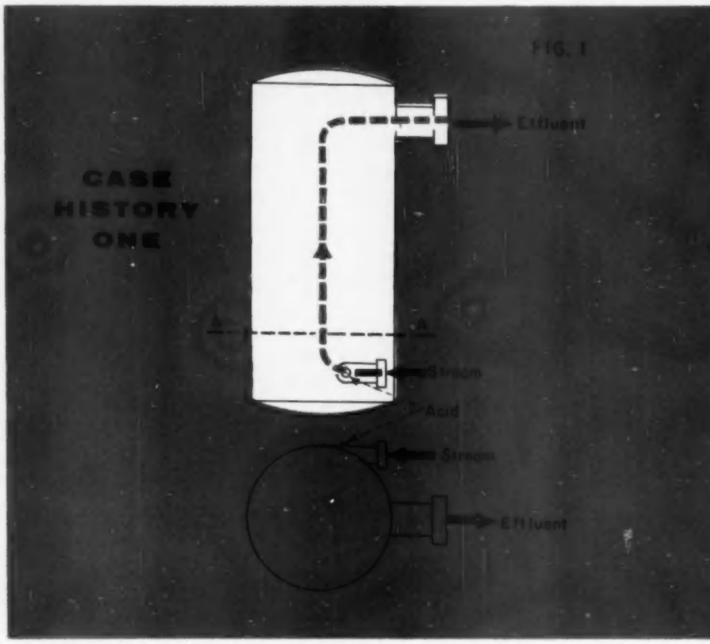
For example, when a code group designated for track 1 reaches the "D" level, switch S1-2 will be actuated but switch S7-8 will be unaffected. Therefore, switch S7-8 is free to handle a subsequent code group that may reach "D" level simultaneously with track 1 code group. This particular mode of operation permits the flexibility necessary in an efficient classification system, but such flexibility is superfluous in an indicating panel.

When a car is classified by this system, track relays associated with approach sections to each switch cause the code group for each car to cascade through the decoding unit in time relation to the progress of the car. The last remaining ball in each code group controls the appropriate switch in each level.

▶ **Discard return tubing—terminal hopper—ball return conveyor system.**

As each code element completes its function, it drops through gutters or tubing to the terminal hopper. A small conveyor system elevates the balls to the return hopper, which completes the cycle through the machine. The conveyor system has sensing elements that detect balls in the terminal hopper and automatically start and stop the conveyor system as needed.

Here are four case histories which demonstrate the progressive penetration of control engineering at the final process design stage, the preliminary process design stage, and the research stage.



Coordinate Control Engineering With Process Development

G. H. BURNETT, Corn Products Refining Co.

A PROCESS IS A SERIES OF OPERATIONS—chemical, mechanical, or electrical. Its purpose is the making of one or more products. Regardless of the type of product or the width of specified tolerances, some degree of control (manual or automatic) over the process is required to get the desired end results. Every process must be a controlled process.

During the development of a new process, the process design engineer concentrates on the chemistry or mechanics. In preparing the equipment specifications he draws upon information from manufacturers and designers of such equipment, as it is his responsibility to keep abreast of new developments in the field. He must exercise the same care in applying instrumentation and control. In fact, only by studying the control requirements at each step in process design does the designer realize the maximum effectiveness of both the process equipment and control. It is not sufficient to consider control requirements as an afterthought to the chemical or mechanical design of the process. Thus, many processing companies coordinate efforts of their process, equipment, and control engineers.

A few case histories illustrate this coordinated effort and also show how far and how early control engineering can penetrate process design.

This article is a condensed version of an unpublished ASME paper number 48-IRD-3.

FIG. 2

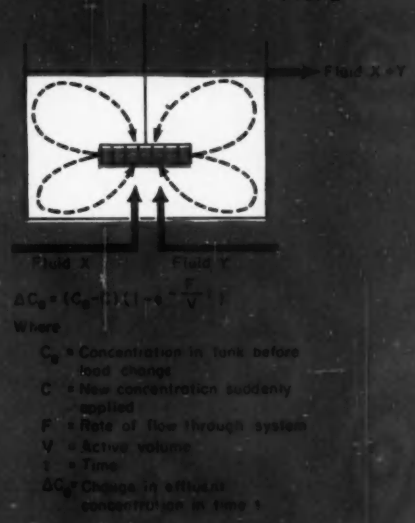
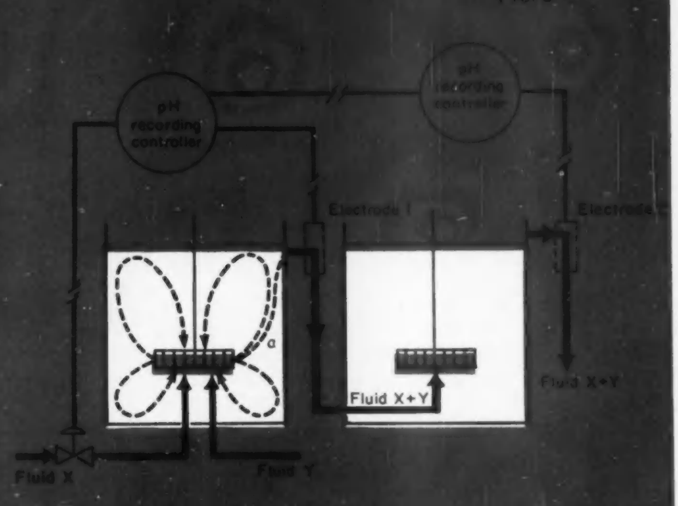


FIG. 3



CASE HISTORY ONE—
Rapid Chemical Reaction

Midway in a chemical process under final design, a unit operation involved the addition of acid to the main process stream to lower its pH to a definite value. Since the reaction was rapid, little holding time was necessary, but the designer felt that a large process capacity would reduce the effect of sudden process load changes and specified a ten-minute holding time. With this holding time the high flow rate through the system would have required an extremely large tank at a proportionately high cost.

Because of the building layout, the process equipment preceding the chemical reaction was on one floor and the equipment for the rest of the process was on the floor above. To save floor space and to make direct connection between the successive operations, the elongated tank shown in Figure 1 was proposed. Introduction of the acid and the process stream at the bottom of the tank would have provided some mixing and circulation. But little agitation would have occurred above section A-A. Since no solids were present to settle out, additional agitation requirements had not been considered up to this point in the design.

It is true that the tank would have provided a ten-minute holding time, but it would have also introduced a long transportation lag, since the measuring element was to be located in the effluent line. Had a load change occurred in the process, requiring the addition of more or less acid, the system would not have detected the change for almost ten minutes.

Result: a continuously oscillating pH value, the maximum and minimum of which would have exceeded tolerances.

The control engineers immediately recognized:

▶ The process as proposed was uncontrollable.

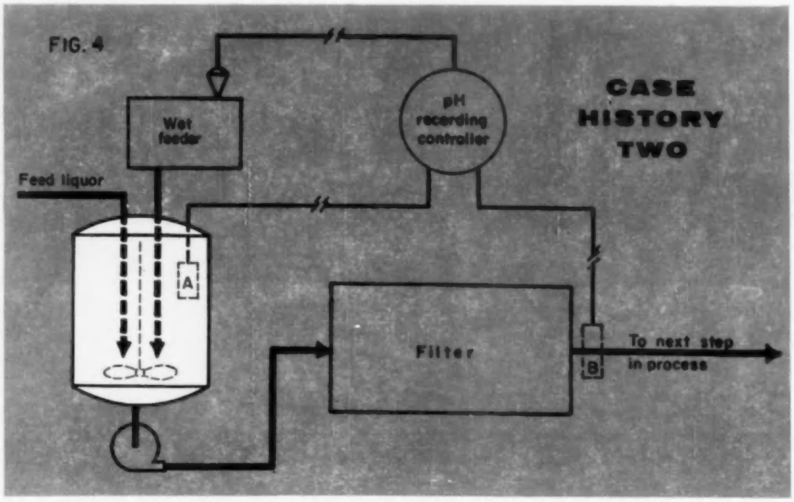
▶ The large capacity would not be objectionable in itself, but would be far greater than necessary.

▶ A smaller tank, properly shaped and with enough agitation to eliminate the transportation lag, would solve the problem.

The tank was redesigned. Its size was reduced to the equivalent of the volume below section A-A in Figure 1, without increasing the floor space it occupied. Mechanical agitation was provided.

Accomplishment: satisfactory control.

The equation given in Figure 2 may be used to determine the tank size for a single-tank installation of this type. The equation describes the uncontrolled approach of the concentration change ΔC_e to the steady-state change $(C_e - C)$ following a load change. ΔC_e must never be greater than the maximum allowable deviation from the control point. Consequently, if the allowable ΔC_e and the stream flow rate are known, t may be made equal to the total lag of process and instrumentation and the equation may be solved for V, which represents that portion of the tank volume that is so well agitated that its concentration is uniform throughout. If the tank diameter is approximately equal to its height and the agitation is sufficient for distribu-



tion, V will represent the entire tank volume. The effort: make V as small as is practical and economical. The result: minimum reaction time and proper control as long as transportation lag is carefully avoided. The economics of tank sizing enter as a balance between size and agitation requirements.[1]

This is the history of a rapid reaction. Where the reaction is slow, additional holding time is necessary before the final concentration is measured. A small portion of the process stream flows directly from inlet to outlet, as shown by the dotted line (a) in Figure 3, and may not stay in the tank long enough to react completely. If the reaction rate is extremely slow, a lot of unreacted liquor flows forward, and a concentration measurement at the tank effluent is not a measure of final concentration. Further reaction occurs after the measurement. To handle this case, two or more tanks usually are placed in series. Their concentrations are controlled by the cascade system shown in Figure 3. Fluid X is admitted to the first tank to satisfy the pH measurement of Electrode 1. The reaction goes to completion in the second tank where the effluent pH is measured by Electrode 2. The second controller adjusts the set point (reference value) of the first controller to maintain the desired end point at the effluent of the second tank. The equations for sizing the tanks and for determining agitation power are more complicated than those for the single tank.[1]

CASE HISTORY TWO—
Delayed Non-Linear Reaction

Figure 4 illustrates the problem at the preliminary layout stage. The problem: by automatically controlling the addition of barium carbonate slurry, neutralize to a given pH a liquor previously acidified with sulfuric acid. Provide a mixing tank of the proper size and shape with adequate agitation. A wet feeder (Ed.—see page 55 of Vol. I, No. 2 of CONTROL ENGINEERING) adds the barium carbonate at a rate adjusted by a pneumatic pH controller. Pump the effluent to a plate and frame filter press to remove the product of neutralization, barium sulfate.

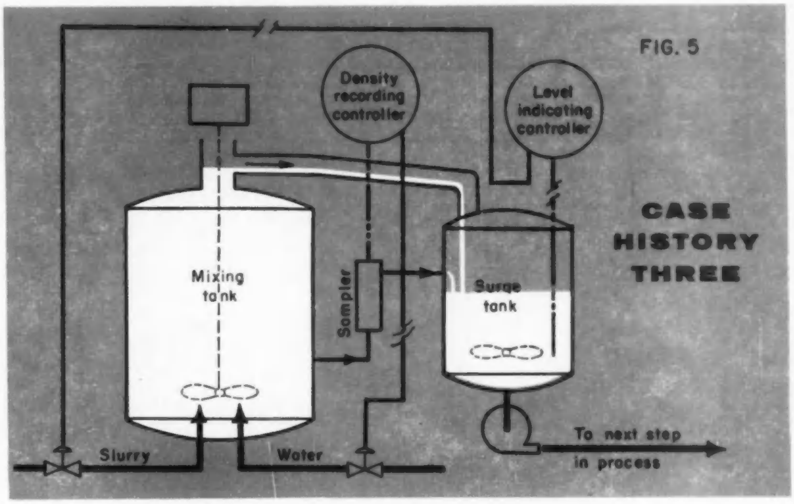
Discussion between process engineers and control engineers revealed that the neutralization was slow and that because of the low solubility of barium carbonate, each slurry particle would tend to coat over with barium sulfate. This would leave each particle with a center of unreacted barium carbonate. Additional neutralization would occur during filtration. It would be impossible to predict final neutralization by controlling the pH at the mixing tank with the immersion electrode A, because the degree of neutralization would vary with the amount of cake in the filter and with the flow rate through the filter. The neutralization could not be controlled by measuring the pH at the filter outlet with electrode B because the time lag between the addition of the barium carbonate and the sensing of its effect on pH would be too great. Conclusion: this section of the process would not be controllable. Thus, filter neutralization would have to be eliminated, or the amount of neutralization predicted.

Additional pilot plant experimentation showed that a very small addition of hydrochloric acid to the neutralization tank accelerated the reaction to completion in the tank. This eliminated the delayed filter neutralization and solved the problem.

CASE HISTORY THREE—
Automatic Dilution Station

Problem: Dilute a slurry to a desired specific gravity. The preliminary design consisted of a mixing tank with diameter approximately equal to height, and equipped with a turbo-type agitator. The tank was vented at the top. Unfortunately, slurries and viscous liquids pick up a lot of air when violently agitated. The air produces an error in the specific gravity measurement and must be eliminated.

Solution: The tank was redesigned, as shown in Figure 5, by putting the feed at the bottom and overflowing the effluent from the neck at the top. This left only a small liquor surface exposed to the air. Any air pickup at that point flowed forward to the next step in the process. The sample for specific gravity measurement, drawn off at a lower level in



the tank, was almost entirely free of air. Accurate specific gravity measurement resulted. Because it was necessary to dilute the slurry at a rate dictated by the next step in the process and because the diluting liquid flow to the tank was regulated by the specific gravity controller, there had to be a way to regulate the undiluted slurry feed rate. Enough had to be added to keep the tank full and to overflow the amount required for the next step in the process. The neck of the tank was too narrow and had too small a capacity for level control at some point above the overflow line. A surge tank of adequate capacity for accurate level control was added.

Here again, time and expense were saved through the cooperation of the process engineer and the control engineer while the process was still on the drafting board, long before construction had started.

CASE HISTORY FOUR—
Process Alteration to Make Control Possible

The final case is an illustration of cooperation from the time that a new product was conceived by the research department until the processing plant was put into production.

A chemical had to be separated from a waste solution containing large quantities of soluble salts. The undesirable salts could be precipitated by addition of lime slurry, and the chemical could be recovered from the filtrate in an almost pure state by further processing. If insufficient lime were added, all of the undesirable salts did not precipitate; and if too much lime was added, some of the valuable chemical precipitated along with the salts.

pH gave the best indication of the correct end point, but it was difficult to measure because secondary reactions occurred before the desired pH was reached. Following the addition of lime to a sample, the pH rose and then, after agitation, drifted down. When more lime was added, the pH rose slowly and then sharply to a pH higher than that at the desired end point. Curve A in Figure 6 is the result of long drop-by-drop titrations with a very dilute lime slurry. The end point occurred along the sharp rise following the second plateau. Control of a single-step process was impossible. The problem was solved by neutralizing to the first pH rise, which was controllable. The salts causing the second plateau were removed by filtration. The titration then followed curve B, allowing accurate end-point control along a linear characteristic.

In brief, the four case histories outlined above illustrate the following points:

▶ Process capacity is important. The minimum capacity can be accurately calculated.

▶ Speed of reaction must be carefully considered in chemical processes.

▶ Even the shape of a tank can effect the control of a process.

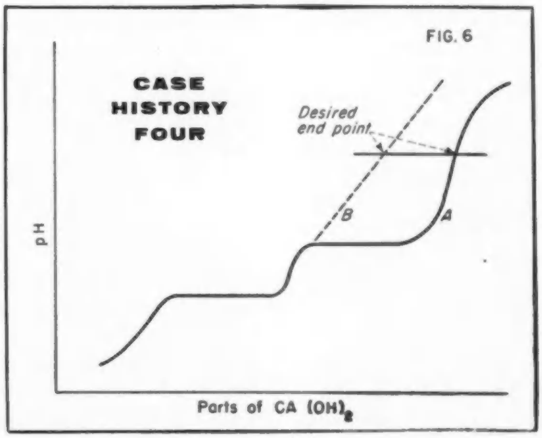
▶ Time lags in a control system are important.

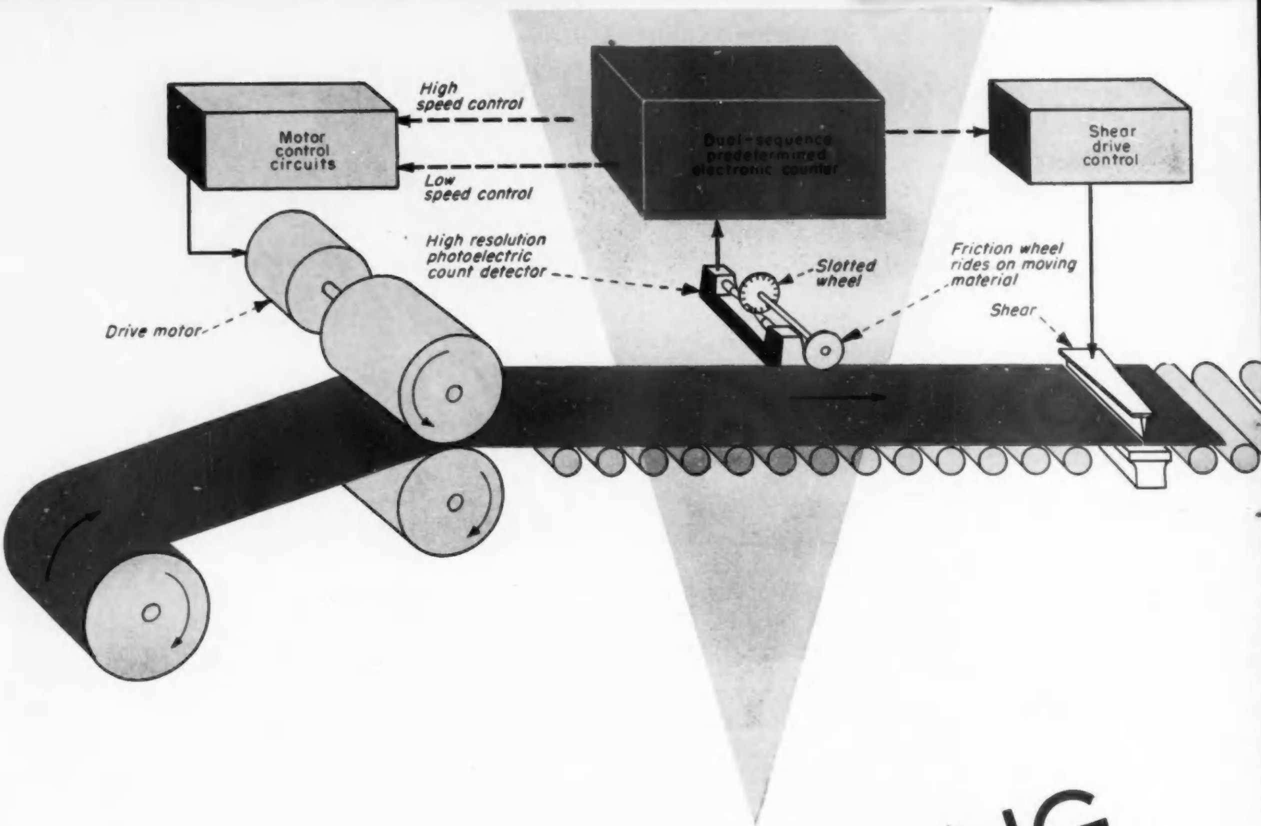
▶ Agitation in a controlled process must be carefully engineered.

▶ Even the shape of a tank can affect the control

▶ Only through coordinated engineering efforts can process equipment and equipment for measurement and control be brought together.

(1) *F. W. VELGUTH AND R. C. ANDERSON*, "Determination of Minimum Capacities for Control Applications," ISA Paper No. 53-6-3.





Electronic COUNTING

A facile electronic counter becomes a control instrument with unusual practical advantages. Here are five application studies to help the control engineer put electronic counting to work.

JAMES D. FAHNESTOCK, Buffalo, N. Y.*

MOST PHYSICAL QUANTITIES dealt with in industry are normally specified in increments—in inches, gallons, revolutions, pounds, and fractions of them. Hence it would be logical directly to measure and control these quantities by digits. Further, rates could be easily handled, since it would be necessary simply to measure the number of increments during a specified time period to arrive at accurate rate information.

In the past few years, high speed electronic counters have contributed to this new digital approach to industrial control. Three characteristics have fostered this:

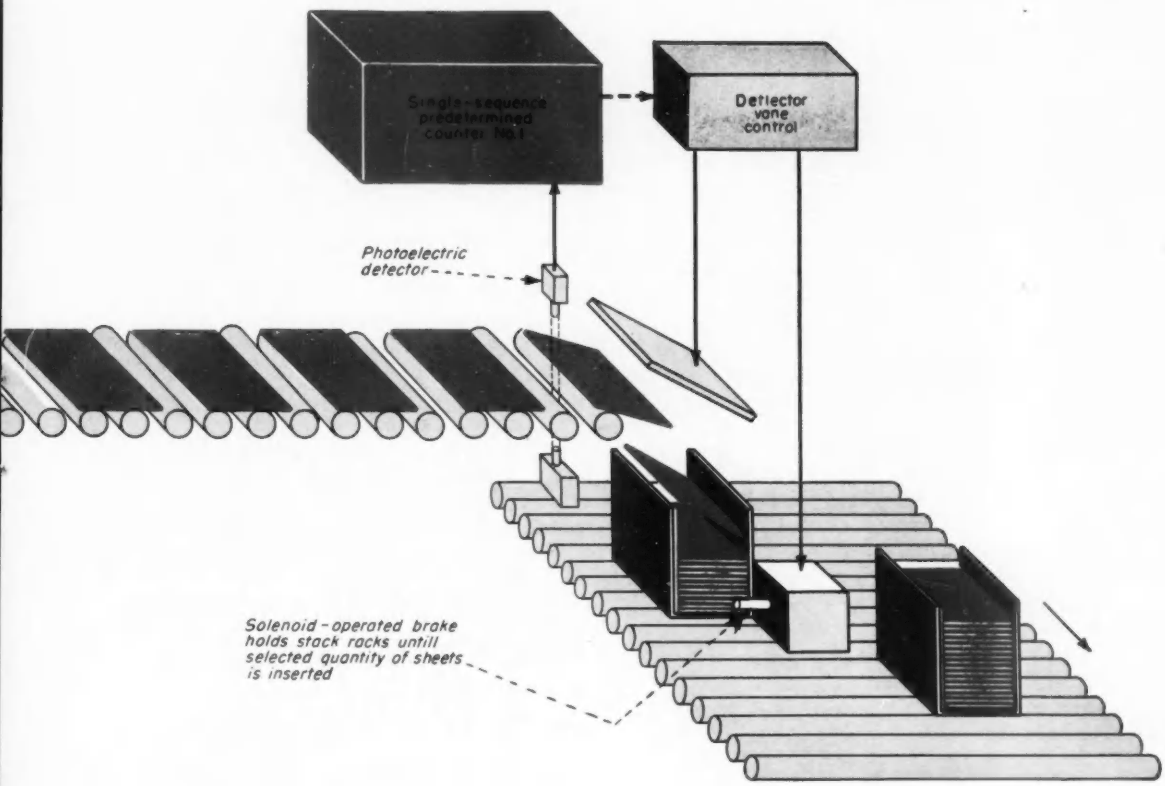
- *Speed and Accuracy*—counters are available which can register over a million events per second. Hence resolution is almost limitless.
- *Functional Ability*—electronic circuitry lends itself to a variety of control functions based on preset digital and time quantities.
- *Flexible Application*—Use of the counter depends on design of suitable transducers to convert measurement of variables to pulse output.

To understand better how inherent design in electronic counters contributes to these abilities, let us see how the instrument works.

HOW IT WORKS

Briefly, an electronic counter consists of an assembly of vacuum tubes that act like a series of chain-reacting on-off switches. An electrical signal —properly shaped and amplified—is the count input to this system. This signal, or the total of a series

* *Formerly with Potter Instrument Co., Inc.*



Moves Into Control

APPLICATION STUDY NO. 1:

STRIP MILL CONTROL

In this application two preset counters are used to make an industrial strip-cutting process fully automatic. A dual-sequence counter controls strip length. Another counter sets-up sized stacks and can control total production.

To gage moving lengths a friction wheel rides the material. This couples to a slotted wheel, which interrupts the beam of a high-resolution photoelectric detector thereby generating counts. Friction wheel circumference and number of slots can be varied, allowing virtually any relationship between pulses and material movement to be established.

For example, pulse rate could be 2 per in. This would give a dimensional accuracy within .5 in. To cut a piece 100 in. long, the counter is set to actuate the shear at a count of 200.

In system shown an automatic drive slow-down permits shear operation. One sequence of the counter automatically slows the drive before cutting. The second counts at the slower speed and actuates the shear at true piece size. The high-speed control then takes over for the next cycle.

Stacking of cut sheets is handled by a single-sequence counter. It operates a deflector vane to route pieces into a new stack as each batch is built. A conveyor is integrated into the system to sequentially move completed stacks.

Another preset counter can be used to count production and shut down the line at a desired end-value. This could be an auxiliary function.

of such pulses, is identified by numbered glow indicators on the display face of the counter.

A popular version of the electronic counter is a cabinet assembly of unit plug-in cascade counting strips. Each strip has four cascaded binary tubes, with associated capacitors and resistors, which are set up to cycle completely in ten steps.

The binary tube acts like a fundamental flip-flop storage circuit. It consists of two resistance-coupled triodes with dc intercoupling. Hence, when one triode is conducting, the grid of the other is held below cut-off by the dc coupling between the two sections. The circuit will remain in this state of equilibrium until caused to flip over by an incoming pulse signal. This signal then triggers a cascading reaction through the four stages.

At the end of its cycle—caused by ten such changes—the decade produces an output pulse, which drives still another decade strip. Thus a chain of decades can be built up to count in tens, hundreds, thousands, and even multi-millions.

Another, more compact type of counting unit is the cold-cathode decade counter tube. This average-sized vacuum tube contains ten cathodes that have their connections brought out on the tube base. A complete cycle of ten is rounded out by pulses moving around this circle of cathodes—much like a driving switch. The count is determined by the position of the glow on a numbered display dial at the end of the tube. Output pulse from the tenth cathode drives subsequent counting stages.

Although the cold-cathode or glow-transfer counting tube is much more compact and simple in circuitry, it is at present limited to count rates less than 20—30,000 cps.

An important part of any electronic counter is an appropriate input circuit to shape and amplify incoming signals. For although these may come in as any type of square-wave voltage pulse, their amplitude and polarity must be shaped to that required to drive the counting decade.

Preset Function

At the end of a series of counts the electronic counter will issue a signal impulse that could actuate a control device. However, most control applications require such a signal at some preset count number, or stage in the process or operation. Further, it is usually required that the counter recycle to zero immediately after final control pulse and before a new series of measurement.

Preset and recycle function has been added to the electronic counter in a fairly simple manner. All numbered drive stages that actuate glow indicators on the counter are simply wired into selector switches. The switches can then be set to the appropriate number in each stage for any total preset count. The output pulse at this count then resets the unit and triggers a control elsewhere.

Stated simply, preset is accomplished in this way: output pulses from the number selected in each decade are brought—through selector switch routing—to a common coincidence circuit. When all pulses coincide, the coincidence circuit itself puts out a signal at the exact preset count.

It is possible also to control more than one operation by means of multiple sequence action in the counter. Thus one output is produced on completion of one selected count, with the unit then immediately reset to count a completely independent number for control of a second sequential operation.

Additional capabilities can be easily built into the electronic counter to extend its measurement and control function. For example, a precise timing circuit will allow the unit to read out the exact number of incoming events within a specific period. This permits it, for example, to read frequency directly, or express speed as rpm.

By adding a precise fixed-frequency source inside the counter—such as a crystal oscillator—it then is able to determine directly the time interval between two external occurrences.

NEEDED: TRANSDUCERS

While functional possibilities are wide, the basic problem in applying counters in industry is the development of suitable transducers, or count detectors.

The function of the count detector is simple. It must produce sequential electrical pulses corresponding to incremental advances in the variable involved. However, although the means to produce this pulse output may be common to many transducers, each has to fit the special and physical needs of the particular process or operation. In other words, count detectors often must be "tailor-made" and rely on the imagination and inventiveness of the engineer designing the system.

Count detectors take many forms, but they may be classified in accordance with the transducer that produces the pulses; that is, photoelectric, electromagnetic, impact, acoustic, contact, etc.

One common method is to use a photoelectric detector in conjunction with a slotted wheel to express rotational increments in terms of pulses. The photoelectric detector "looks through" the slots. Each time the light beam is interrupted, a count is inserted in the counter.

It is important to note that the larger the number of counts per increment from the detector, the greater the accuracy. In the strip mill application shown at the opening of this article a 100-slot wheel connected to a 1 in. friction wheel will produce 100 counts to the inch. Cutting is thus controlled to within .01 in.

Counting Rate

Certain types of laboratory counting equipment must count millions of pulses per second. However,

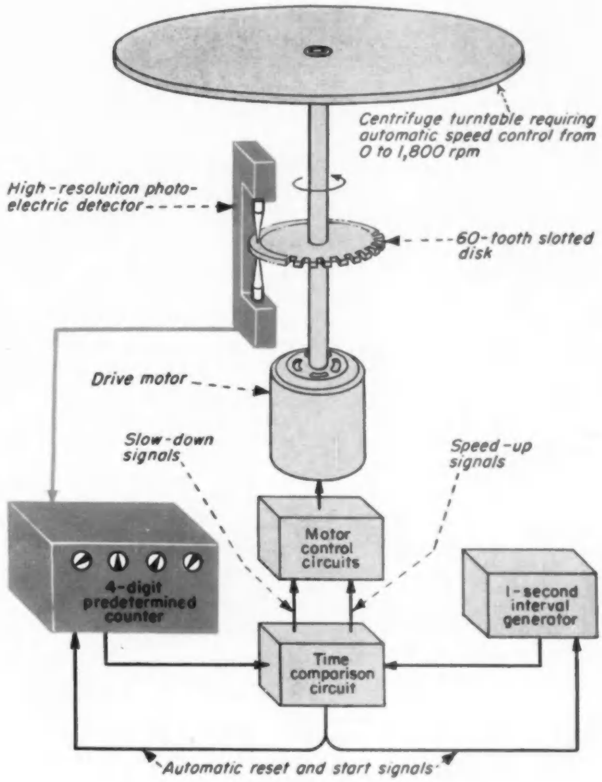
APPLICATION STUDY NO. 2

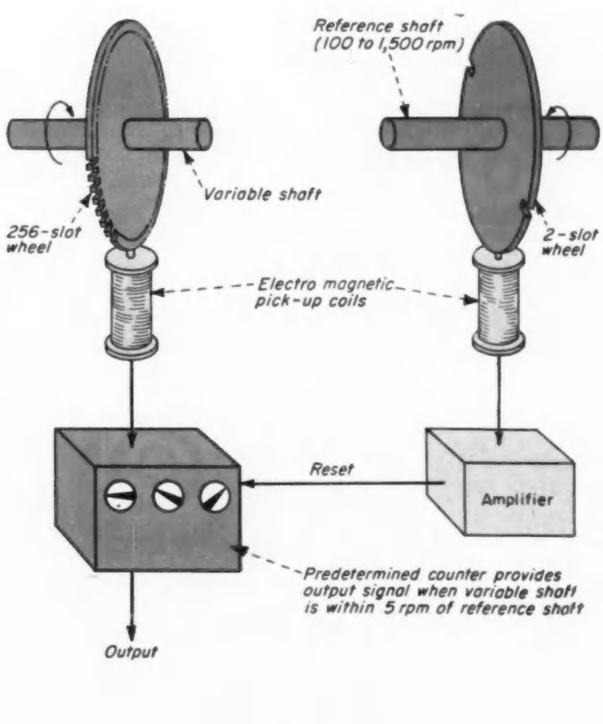
AUTOMATIC SPEED CONTROL

The system shown is designed for plus or minus 1 rpm control of an industrial centrifuge. Desired rpm is simply preset on the 4-digit counter. The control will then bring the system up to speed and hold it there.

A slotted disc produces 60 pulses for every turn of the centrifuge. Each time a number of pulses equal to the selected rpm is developed, the counter produces an output pulse and recycles. The time between reset pulses will be exactly 1 sec when shaft is running at the desired speed. Speed-up or slow-down control signals are produced by a coincidence circuit, which compares total pulses to time interval.

A fairly accurate way to generate the one second reference interval is for the counter to utilize the 60-cycle frequency from the power line. However, greater accuracy may involve counting, say, 100,000 pulses from a 100-kc crystal-controlled oscillator.





APPLICATION STUDY NO. 3

DIGITAL SHAFT SYNCHRONIZER

A preset counter is used here to compare rpm of two shafts and produce a synchronizing control output. A slotted wheel and electromagnetic pick-up on the variable shaft produces 256 pulses per revolution. Reference shaft is set up to produce 2 pulses per revolution.

Pulses from the variable shaft are applied to the counter which is preset for an output signal at 127 input pulses. Pulses from the reference detector reset the counter. Hence as the variable shaft approaches speed of reference shaft, the count registered prior to reset approaches 128 (it would be precisely 128 if both shafts were at same speed). Just before synchronization—at 127 pulses before reset—the counter produces an output that can control external equipment.

the average counting rate in industrial control seldom exceeds 1,000. Such requirements are readily met with standard counter circuits. In fact, counters are often built with frequency response limited to such values. These circuits, however, do protect against spurious counts that can be injected by heavy industrial machinery.

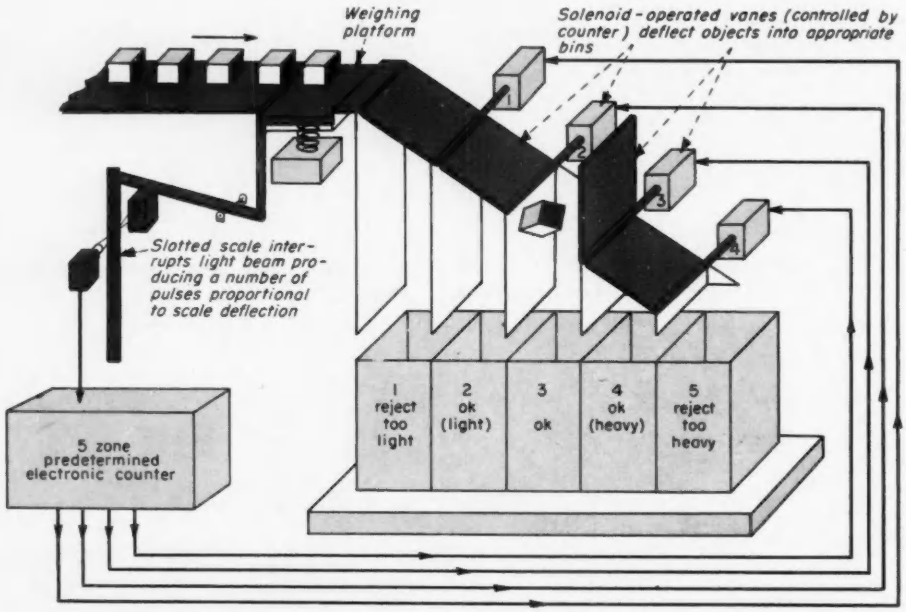
In the strip mill, with material moving at 50 ft per min, and counts at 100 to the inch, counting rate is 1,000 pulses per sec. The same counting rate could apply at twice this belt speed—but resolution would be cut in half.

The slotted wheel also offers convenient approach to rotational speed control. If a 60-slot wheel is used, and the generated pulses are applied to a counter for exactly 1 sec, the counter will indicate revolutions per minute directly. For example, a shaft turning at 600 rpm will cause 10 turns of the 60-slot wheel in one second, giving a readout of 600.

Two alternate techniques are available for controlling speeds by digital means. In one the time required for the shaft to cause a preset number of pulses is compared to time associated with the desired speed. When the preset count is produced too soon, the wheel is turning too fast, and a control signal slows down the drive mechanism.

In the alternate method the number of pulses produced in a given time is compared to the number that would be produced by the shaft at a desired speed. Too many pulses indicates excessive speeds; two few indicates the shaft is turning too slowly.

NOTE: A second article on the subject of industrial counting will appear in a future issue. It will concern the design and application of count-detecting transducers.



APPLICATION STUDY NO. 4:

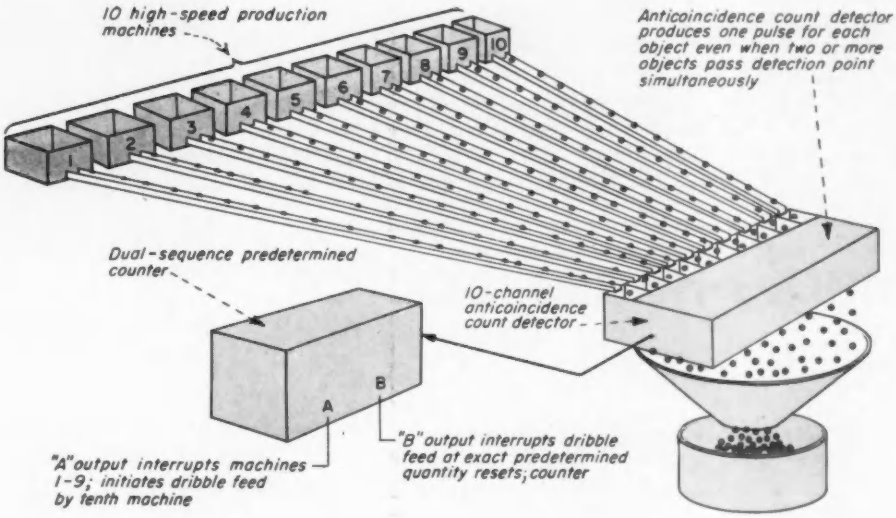
AUTOMATIC ZONE CLASSIFIER

In this application a 5-zone preset counter is tied into a conveyor-type weighing system to classify moving objects by weight.

The system indicates that the weighing platform in the conveyor is mechanically linked to a slotted vertical rule. The latter passes between the pick-up beam of a photoelectric detector, which pulses the counter. The number of pulses per object is proportionate to weight.

In this case the counter is preset to produce four separately routed output signals. These trigger, solenoid-operated deflector vanes, which route each object into an appropriate bin.

Many variations of this type of classification can be developed. Chevrolet springs, for example, are classified by a 5-zone counter, which totals pulses from their deflection in a compression tester. Here, five paint sprays are actuated to code the classified springs.



APPLICATION STUDY NO. 5:

MULTIPLE-CHANNEL COUNTING

A dual-sequence counter is shown here controlling total production of small parts from ten machine lines. Parts pass through a compact bank of photoelectric detectors. To detect simultaneous passage of objects, an anticoincidence circuit serves the bank.

This is essentially a simple electronic memory, which will apply two or more distinct pulses to the counter if objects happen to pass beams at precisely the same time.

To control down to one part, a dribble-feed system is used. First sequence of the counter is set to total parts less ten—and this signal shuts down nine of the lines. The line still running then produces until the second counter sequence recognizes the desired total, and production automatically stops.

HOW TO SPECIFY A COUNTER

Most industrial control applications of preset counters differ only in the method of producing counts and the requirements of the machinery controlled. To suggest the most economical and satisfactory systems, certain fundamentals should be specified to the counter manufacturer. These are:

1—*WHAT IS THE QUANTITY TO BE CONTROLLED?* The answer should include complete information as to physical nature of the material.

2—*WHAT TYPE OF INCREMENTS ARE INVOLVED?* In other words, inches, feet, pounds, degreess, revs, etc. What resolution is required?

3—*WHAT COUNTING RATE IS REQUIRED?* This figure may be arrived at by multiplying smallest increment by processsing rate. Rates below 1,000 per sec are usually desirable in heavy vibration areas.

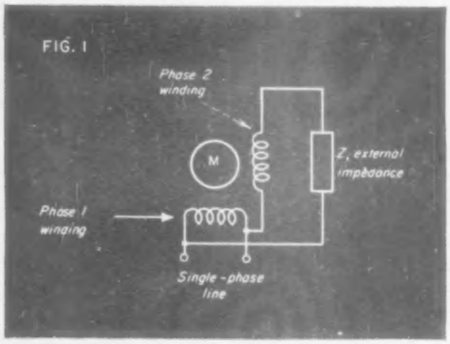
4—*WHAT IS MAXIMUM COUNT ANTICIPATED?* With weight, for example, unit may be pounds and each pound may be divided into 1,000 parts. If maximum quantity were 50 pounds, a count capacity of 50,000 would be needed.

5—*WHAT TYPE OF COUNT DETECTOR IS PREFERRED?* Physical environment greatly influences the type of pickup. Mustiness may preclude photocells, and noise might rule out acoustic detectors.

6—*HOW MANY COUNT SEQUENCES ARE INVOLVED?* One operation usually calls for a single sequence counter. But if slow-downs or sequenced steps are required, a multiple-sequence instrument is indicated.

7—*WHAT TYPE OF EQUIPMENT IS TO BE CONTROLLED?* The answer here should include complete electrical requirements of equipment to be controlled when a count sequence is completed. Relay contact arrangements or pulse outputs can then be specified for the job.

How to Operate a Two-Phase Motor from a Single-Phase Source



This is the usual arrangement for equivalent operation. An external phase-shifting impedance is connected in series with one motor winding.

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SINCE THE INTERNAL impedance of a motor winding varies with motor speed, equivalent two-phase and single-phase operation can be obtained for one motor speed only, unless the external impedance is varied with motor speed. In practice, particularly for servomoters, it is possible to choose an impedance that performs satisfactorily over the entire speed range of the motor.

The impedance at a given speed and the rated voltage for both phases can be obtained from the catalog values published by the motor manufacturer. Then the external impedance required for complete equivalence is given by

$$Z = \left(\frac{E_1}{E_2}\,X_2 - R_2\right) - j\left(X_2 + \frac{E_1}{E_2}\,R_2\right)$$

Z_2 = impedance of phase 2, ohms
R_2 = resistive component of the impedance of phase 2, ohms
$X_2 = \sqrt{Z_2^2 - R_2^2}$
X_2 = reactive component of the impedance of phase 2, ohms
E_1 = rated voltage of phase 1, volts
E_2 = rated voltage of phase 2, volts

Generally, the required external impedance has both a resistive and a capacitive component. Sometimes, the resistive component has a negative value—impossible with passive components.

In practice, the resistive component of the external impedance is neglected, and phase shifting is accomplished by a capacitive component only. The value of the capacitor is given by

$$C = \frac{10^6}{2\pi f\left(X_2 + \frac{E_1}{E_2}\,R_2\right)}$$

f = frequency, cycles per seconds
C = capacitance, microfarads

To assist in determining the capacitance required for equivalent operation, Figures 2 and 3 show the capacitance C in microfarads for both 60 cps and 400 cps operation.

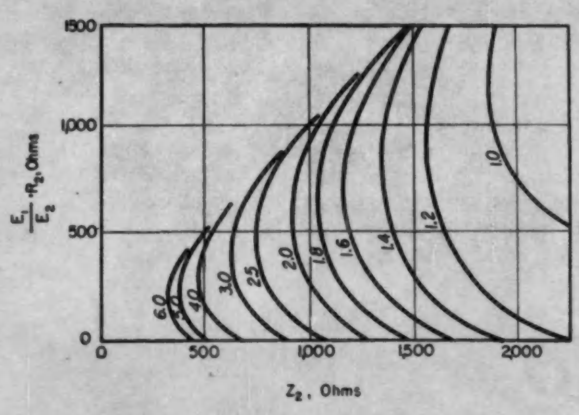
Example: Find the capacitance for the equivalent operation of a two-phase motor where; f is 400; E_1 is 115; E_2 is 230; Z_2 is 2,000; R_2 is 1,300.

Referring to Figure 3, a vertical line drawn through Z_2 equals 2,000 ohms, intersects a horizontal line drawn through

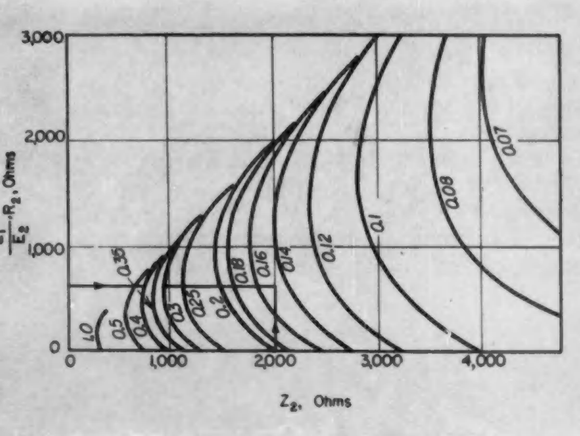
$$\frac{E_1}{E_2}\,R_2 = \left(\frac{115}{230}\right)1{,}300 = 650 \text{ ohms}$$

The point of intersection lies on the curve marked .16 microfarad. This is the value of the capacitance required for equivalent operation.

Capacitor values in microfarads for equivalent single-phase operation on 60 cps. FIG. 2



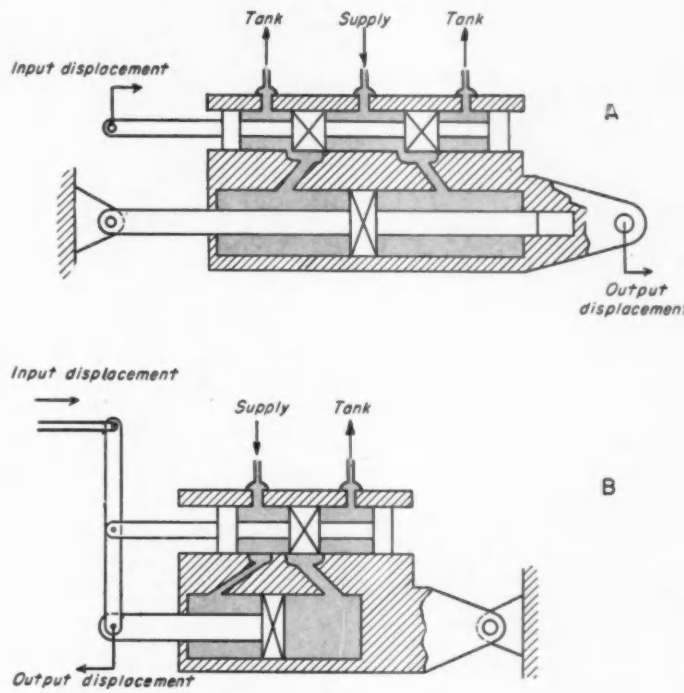
Capacitor values in microfarads for equivalent single-phase operation on 400 cps. FIG. 3



TIE THEORY TO PRACTICE IN

Aircraft Booster Design

Even the best-designed of these hydraulic servos often need modification after test-rig and flight trials. But theoretical analysis helps engineers design boosters much more nearly ideal for their exacting task.



Two hydraulic servo configurations. (A) shows a four-way valve arrangement with inherent feedback. Flow is controlled to both sides of piston. (B) shows a three-way valve with lever feedback. Rod side of piston is always exposed to supply pressure, while flow to blind side of piston is controlled. FIG. 1

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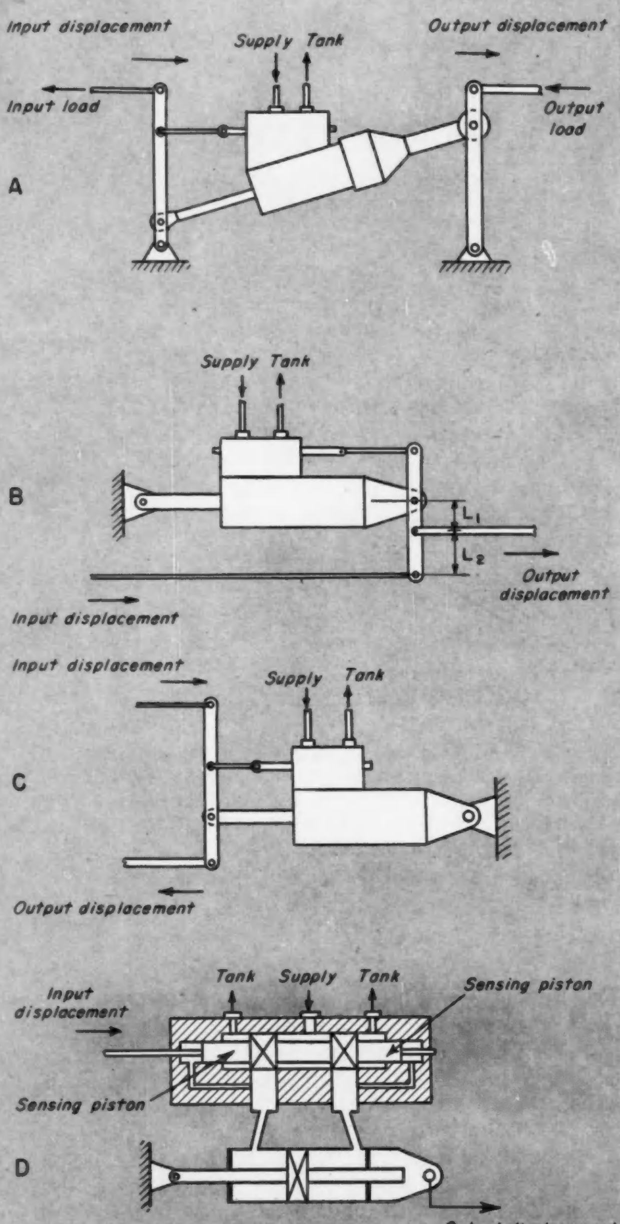
THERE ARE TWO ASPECTS TO THE DESIGN of powered controls for aircraft. First the controls must be considered as components in an overall system, and their performance must be correlated with such factors as the aerodynamic characteristics of the aircraft and the response characteristics of the pilot. This systems approach was covered in "How to Fit Power Boosters into Aircraft Controls," CONTROL ENGINEERING, Dec. 1954.

Once booster requirements have been determined, the detailed design work must be carried out to give a unit that will conform to them. This consists of selecting a basic booster configuration and modifying it and specifying dimensions to obtain desired performance.

Figure 1 shows two basic arrangements of cylinder-valve-type hydraulic servos. Both of these are essentially fully powered controls (input force has to overcome only valve friction and valve axial forces), and slight modifications are necessary if the input is to be accompanied by a load proportional to output load (booster control in which pilot obtains feel by having to supply a part of the force required to move

ALL BOOSTER ARRANGEMENTS STEM FROM THESE 4 BASIC SCHEMES



Examples of booster arrangement. Although in practice the finished design may look different, usually the units are derivations of these basic arrangements. FIG. 2

the control surface). Feel is usually introduced by levers or by sensing pistons on the valve.

Some examples of booster arrangements are shown in Figure 2. While the final design may not resemble one of these, it will probably be a derivative of these basic types.

Aircraft hydraulic servos differ from industrial models in that they are governed by principles of aircraft structural design. The cylinder is usually pin-jointed to avoid lateral loads that increase friction and produce troublesome stresses. Also the cylinder is usually an expanding member in a mechanism, for example a four-bar linkage. Components must have a minimum weight consistent with satisfactory strength and performance and since the loads are high, problems of elastic deflection often complicate servo performance. This particularly affects cylinder mountings and cable runs.

Since a satisfactory control is vital to aircraft safety, it is necessary to carry out an extensive test program both on test-rigs and during flight trials. All too frequently these tests lead to extensive modification of the booster design. Nevertheless, there are factors affecting performance that can be assessed initially during design stages, and in this respect the value of theoretical analysis should not be underrated.

PRACTICAL DESIGN CONSIDERATION

The practical considerations in cylinder-pilot valve hydraulic servo design stem from inherent limitations in the mechanical design and application of the system and from inherent limitations in fluid characteristics. These can be divided into two groups, depending on whether they are encountered in any servo of this type, or whether they result from using the system as an aircraft power booster. Some of the factors that are characteristic of servos of this type will be covered first.

Valve nonlinearity

The flow from the pilot valve to the cylinder varies both with the valve displacement, x_v, and with the pressure drop across the valve, P_s minus P_c, in accordance with the relation

$$Q = f(x_v)[P_s - P_c]^{1/2} \qquad (1)$$

And since the differential operating pressure in the cylinder, P_c, varies with output load and thus with output displacement, x_o, this constitutes a nonlinearity in the system (in a mathematical sense). Performance in general, and particularly stability, deteriorates because of this nonlinear effect, but its effect can be restricted by limiting the maximum value of P_c. Maximum power output from the valve is obtained when

$$P_c = \tfrac{2}{3}P_s$$

Generally this pressure will give satisfactory overall performance.

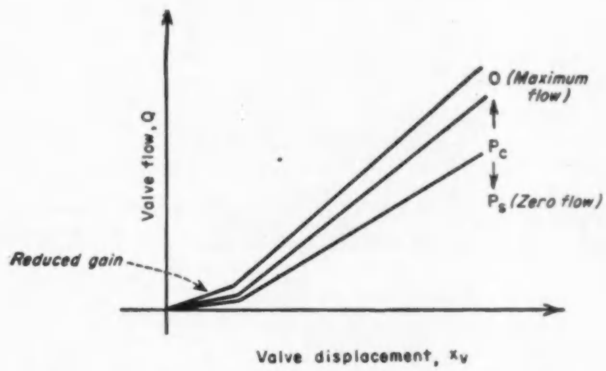
The shape of the valve flow curve is determined

NOMENCLATURE

x_o = control output displacement
p = Laplace operator
$j\omega$ = frequency vector
x_i = control input displacement
F_D = external force on control surface as seen by power control
F_o = total surface force seen by power control
$I_1(\omega), I_2(\omega)$ = real and imaginary parts of unit impedance vector $(F_o/x_o)(j\omega)$
Q = flow from valve to cylinder
P_s = system pressure of hydraulic supply
P_e = differential cylinder piston pressure
x_v = valve displacement
A = cylinder piston area
N = effective bulk modulus of hydraulic fluid
V = half of total fluid in hydraulic cylinder
R = boost ratio
ξ = follow-up ratio
$\overline{F}_e$ = output load at which follow-up ratio is reduced
L_1, L_2, L_3, l_1, l_2 = lever dimensions
$L = L_1 + L_2 + L_3$
$l = l_1 + l_2$
y = cylinder piston displacement
e = valve link input displacement
x_p = sensing piston displacement
A_p = sensing piston area
k_p = sensing piston spring rate
Z_o = output load impedance, denoting aerodynamic spring and damping loads together with inertia load, as seen by booster
K = gain of valve
k_v = stiffness of valve
k_j = stiffness of cylinder
k = constant
ξ' = reduced follow-up ratio $= \xi/k$
ω_b = approximate bandwidth

$$C = (1 - \xi)\frac{(R-1)}{R}\frac{l}{l_1}$$

M = inertia of output as seen by control
k_a = output spring rate as seen by control
F_i = input load applied by pilot



Valve characteristic showing flow versus displacement. Reduced gain portion improves stability near neutral position. FIG. 3

by the form of f (x_v), Figure 3. By varying the relation of valve opening area to valve travel (for example, by making the valve port a row of spaced holes) almost any desired curve can be approximated. For convenience, the curve is usually made a straight line. The slope of this line determines valve gain and therefore the sensitivity of the unit.

Because of the "square-law" damping of the valve ports, it is usually found that stability is critical in the neutral region of the valve. For this reason, valve gain is reduced in the vicinity of the neutral position.

Fluid Compressibility

The compressibility of the hydraulic fluid in the cylinder causes a destabilizing compliance in the system. The critical condition for stability occurs when the piston is in the half-stroke position, so that the column of oil in the cylinder acts like a spring with a stiffness of A^2N/V. The stiffness is effectively decreased by the presence of air in the fluid. But the bulk modules of the aerated fluid increases with pressure, and in practice a base pressure is maintained in the cylinder by a small leak across the valve lands.

Even with these precautions, fluid compressibility has a serious effect on stability. To compensate for this it is necessary to design the valve to act as a displacement potentiometer in the region of its neutral position. Or in other words, any change in output load causes the valve to displace so as to balance leakage flow across the lands. This can be achieved by overlap with radial clearance on the valve lands, or by a small underlap together with a leak between the two sides of the cylinder.

Output Loading

In flight, the output load consists primarily of an

aerodynamic spring load together with smaller damping and inertia forces. The spring and damping forces generally have a stabilizing influence on the system, while the critical stability condition is encountered when only inertia forces are present. This condition sometimes occurs when an aircraft is on the ground. The inertia and the fluid column in the cylinder form an undamped oscillator that is readily energized by the valve.

Linkage Flexibility

Because of high output loads there must be a rigid mechanical coupling between the cylinder and the control surface. For this reason, the control unit is usually mounted close to the surface. The circuit between the pilot and the control unit is often long and can have considerable flexibility. Although the input loads are small, a long mechanical connection can have a great influence on stability.

Axial Valve Forces

The friction and hydrodynamic forces on the valve stem are the sources of excitation in the input circuit. They are essentially nonlinear, and cause sustained oscillations in the input linkage and thus in the system. For this reason it is necessary to make the natural frequency of the input circuit well above the cutoff frequency of the servo. Often a damper is used between the valve stem and the valve body, although much can be accomplished by reducing the friction forces on the valve.

Mounting Flexibility

Because of high cylinder loads, the mounting attachments must be rigid. Compliance in these attachments increase the flexibility of the cylinder and must be compensated for by the valve. This can have a detrimental effect on the stiffness of the control under output loads.

Friction and Backlash

Friction in the valve and cylinder tend to aggravate oscillations, particularly those caused by fluid compressibility. Backlash can be reduced by the careful choice of bearings and by pre-loading linkages. A general requirement in England is that the total backlash in a system shall not exceed plus or minus .1 deg of surface movement. Unfortunately neither friction or backlash are readily susceptible to mathematical analysis.

Flow Saturation

Output velocity saturates when the valve has been moved far enough to expose full port area. Velocity becomes insensitive to servo error and depends only on differential cylinder pressure. For large displacements the operating time is almost entirely governed by the saturated flow, and is given approximately by the swept volume of cylinder divided by saturated flow.

Usually surface speeds up to about 60 deg per sec are required, corresponding to valve flows between 5 and 20 cu in. per sec.

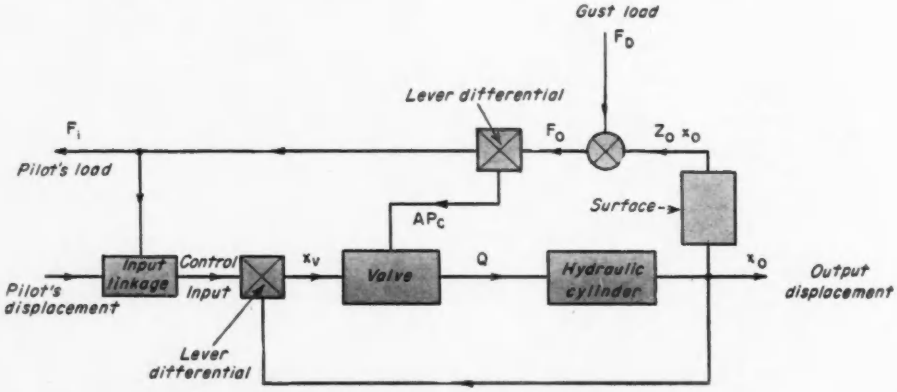
If valve travel is limited by stops that permit the stem to move just enough to uncover the ports, then the input will also be constrained to move at a saturated speed. On some systems an overriding device is incorporated that permits greater input freedom.

Booster Design Factors

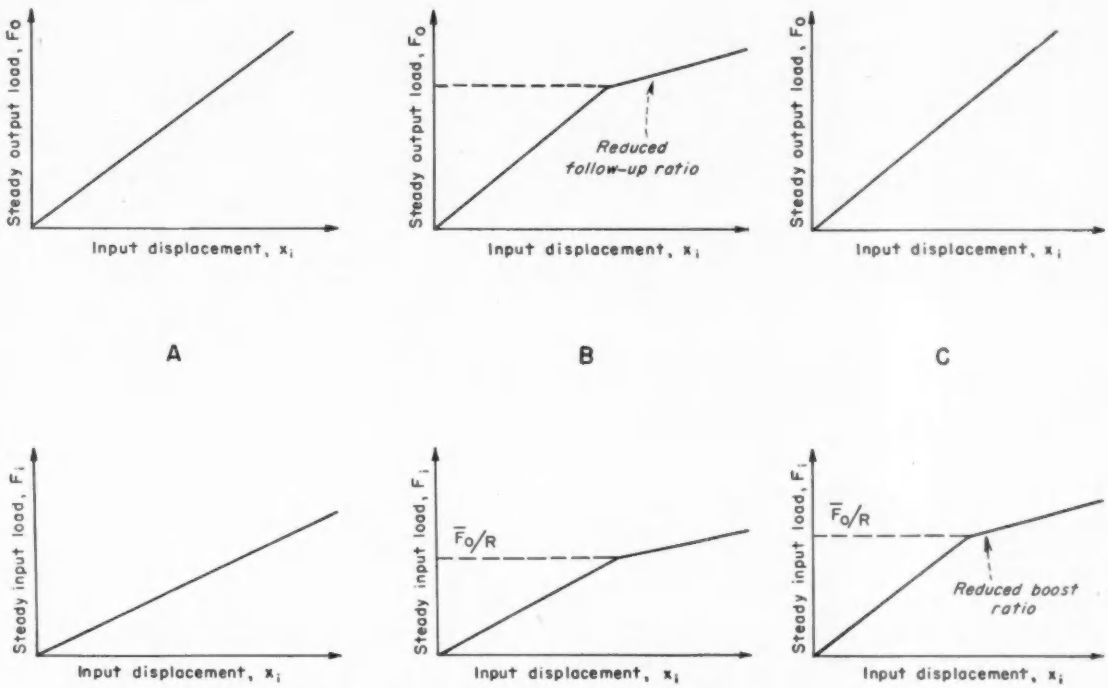
The extent to which the factors peculiar to hydraulic power boosters influence a particular design depends on the layout and size of the unit in question. Here, analysis is helpful. For example, the effect of valve damping force on stability depends on certain linkage ratios and one design may yield better results than another. In this case mathematical analysis can give a fair comparison of the various possibilities.

It is difficult to draw any general conclusions, and it is better to treat each system on its merits. In the theoretical section to follow, a typical booster is analyzed to show the general method of approach.

There are two important parameters associated



Block diagram of booster system showing load feedback into the input. FIG. 4



Steady-state input and output loads plotted against input displacement. (A) shows relation for constant boost and follow-up ratios. (B) shows result of reducing follow-up ratio above a certain load, while (C) shows result of reducing boost ratio above a certain load. FIG. 5

with booster design. These are boost ratio, R, which is the steady-state ratio of control output load to pilot's load (input load), and follow-up ratio, ξ, which is the steady-state ratio of output displacement to input displacement.

Both R and ξ can be changed merely by altering the length of the surface hinge arm without altering the control itself, so that individually the two parameters do not describe the amplifying properties of the booster. An actual measure of the power amplification ratio is the product $R\xi$; nevertheless R and ξ are convenient quantities to use in analysis. When the output displacement is measured at the hinge, ξ is usually about unity, so that R gives an approximate measure of power amplification. Boost ratios are normally about 10:1, but may be higher.

In the systems shown in Figures 2(B) and 2(D), the boost ratios are given by the lever ratio

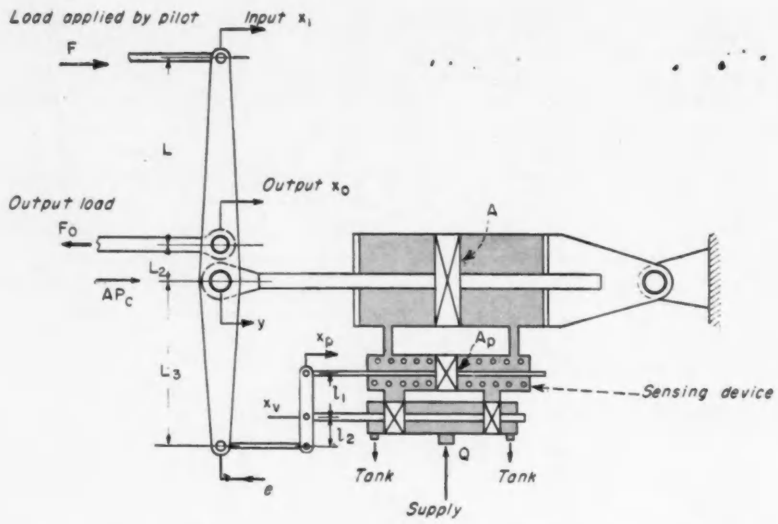
$$\frac{L_1 + L_2}{L_1}$$

and by the ratio of cylinder piston area to valve sensing piston area. The configuration shown in Figure 2(B) has the advantage that the valve can be initially displaced without moving the cylinder piston. In contrast, in Figure 2(D) the cylinder body must be displaced to open the valve. In the latter system, the combined effects of fluid compressibility and valve and cylinder friction often cause serious hunting.

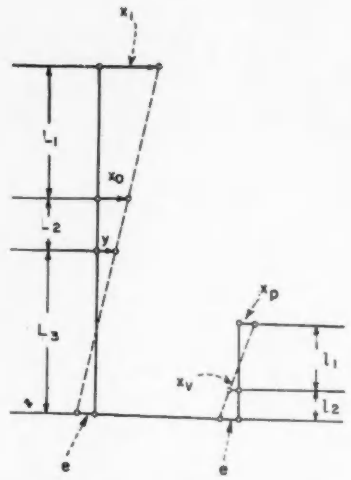
Since the load transmitted by the input linkage is much greater than valve friction force, coupling is introduced between the output and input circuits. This is a major source of instability in boosters and it is usually necessary to provide damping for the input linkage. Figure 4 shows the load feedback into the input linkage.

As previously stated, the control surface load under flight conditions consists mainly of an aerodynamic spring load which is roughly proportional to output displacement. Therefore if the follow-up ratio ξ is constant, the curve of surface load against input displacement will also be linear in the steady-condition. Similarly, if the boost ratio R is constant, then the pilot's load will also be proportional to input displacement in the steady-state condition, Figure 5(A).

To protect against overstressing the airframe of high speed aircraft, it is desirable to limit the control surface load that can be applied through the booster by the pilot. This can be achieved by modifying the control characteristics for large displacements from the neutral or no-load position. There are two ways of doing this:



Booster arrangement with a sensing piston to reduce the follow-up ratio above a certain load. FIG. 6



Line diagram showing the relative link displacements for the configuration shown in Figure 6. FIG. 7

1. The follow-up ratio can be reduced if the output load exceeds a specified value $\overline{F}_o$. This can be done by putting a spring in the output or input circuit with a preset load of $\overline{F}_o$ or $\overline{F}_o/R$ respectively. But such springs must be damped, requiring a separately primed dashpot device (not satisfactory because of leakage). Because of their weight and size, these units are not normally used.

A better method is to use a sensing piston connected across the two sides of the cylinder piston, Figure 6. This device also requires a preloaded spring, but its size and inherent damping are advantages. Figure 5(B) compares the steady-state variations of output load and input load with input displacement against those for a constant follow-up ratio.

2. A second way to limit output load is to reduce the boost ratio for large output loads. This can be accomplished by using pressure limiting valves across the cylinder piston. Figure 5(C) shows the effect of varying boost ratio on the load-displacement curves.

In most designs there is a tendency for the booster to return the surface to the no-load position when the input is unloaded, that is when the pilot takes his hands off the stick. This centering action is preferred by pilots (a reason for artificial feel springs in fully-powered controls), and is often essential to free flight stability of the airplane.

Opposing the centering action is the friction force in the input linkage. For low boost ratios the airloads are usually sufficient to overcome this force; however, when the boost ratio is high and the pilot's load is comparatively light, input circuit friction can seriously impair self-centering. This sometimes occurs in large aircraft where long circuit runs cause high friction forces, and may limit the boost ratio that can be used.

While the safety devices used to ensure that a pilot will not lose complete control in the event of mechanical failure are outside the scope of this article, some brief mention might be desirable. The faults that can occur are hydraulic supply failure and slide valve seizure.

If the supply fails the pilot's stick must be coupled directly to the surface, thus reverting to manual control. This may seriously restrict the pilot's control of the aircraft and it is essential that he be made aware of the power failure.

To overcome valve jamming, an overriding device in the input circuit is usually included. This opens a bleed across the cylinder piston and bypasses the supply to tank. The unit is then effectively on manual control and it is possible that the pilot's exertions will free the jammed valve.

THEORETICAL BOOSTER DESIGN

The following outlines briefly a typical theoretical analysis of a power booster. The analysis is based on the configuration shown in Figure 6. This unit uses a sensing element to reduce the follow-up ratio in the presence of large output loads.

Figure 7 shows the relative displacements of the links, assuming that the output load is sufficient to overcome the preload of the sensing device. The following equations can be obtained from the geometry of the linkage:

$$L_2x_i + L_1y = (L_1 + L_2)x_o \qquad (2)$$

$$L_3x_o - L_2e = (L_2 + L_3)y \qquad (3)$$

$$l_1e - l_2x_p = (l_1 + l_2)x_v \qquad (4)$$

The displacement of the sensing piston is given by

$$A_p(P_s - P_o) = k_p x_p \tag{5}$$

where P_o is the differential cylinder pressure corresponding to output load $\overline{F}_o$.

The flow from the valve is given by Equation 1

$$Q = f(x_v)[P_s - P_c]^{1/2} \tag{1}$$

This is essentially nonlinear. But it can be linearized if only small increments in x_v and P_c about steady-state conditions are considered. By partial differentiation

$$q = \frac{\partial Q}{\partial x_v} x_v + \frac{\partial Q}{\partial P_c} P_c \tag{6}$$

This assumes that for small disturbances $\partial Q/\partial x_v$ and $\partial Q/\partial P_c$ are substantially constant and are functions of the steady-state conditions only. Considering small disturbances only, Equation 5 becomes

$$A_p P_c = k_p x_p \tag{7}$$

The flow into the cylinder consists of a component tending to displace the piston and a small flow caused by the compression of the fluid. Therefore

$$q = A\frac{dy}{dt} + \frac{V}{N}\frac{dP_c}{dt} \tag{8}$$

Finally the differential cylinder pressure is given in terms of the total output load by the relation.

$$AP_c = \frac{L_1}{L_1 + L_2}[Z_o x_o + F_D] \tag{9}$$

Thus for small disturbances, the system response is governed by the linear Equations 2, 3, 4, 6, 7, 8 and 9. Introducing the Laplace Operator p to facilitate the algebraic handling of these equations, the following transfer function can be obtained

$$\frac{x_o}{x_i}(p) = \frac{\dfrac{L_2 + L_3}{L} + \left(\dfrac{l}{l_1}\dfrac{L_2}{L}\Big/\dfrac{\partial Q}{\partial x_v}\right)Ap}{1 + a + b} \tag{10}$$

$$a = \left(\frac{L_1 + L_2}{L}\frac{l}{l_1}\Big/\frac{\partial Q}{\partial x_v}\right)Ap$$

$$b = \frac{L_1^2 Z_o}{L(L_1 + L_2)}\left[\frac{l}{l_1}\left(-\frac{\partial Q}{\partial P_c}\Big/\frac{\partial Q}{\partial x_v} + \frac{Vp}{AN}\Big/\frac{\partial Q}{\partial x_v}\right) + \frac{l_2}{l_1}\frac{A_p}{A}\frac{1}{k_p}\right]$$

With the selected configuration, the following relations hold.

$$R = \frac{L_1 + L_2}{L_2} \tag{11}$$

$$\xi = \frac{L_2 + L_3}{L} \tag{12}$$

The gain of the valve can be expressed by

$$K = \frac{1}{A}\frac{\partial Q}{\partial x_v} \tag{13}$$

the stiffness of the valve by

$$k_v = A\frac{dP_c}{dx_v} = -A\frac{\dfrac{\partial Q}{\partial x_v}}{\dfrac{\partial Q}{\partial P_c}} \tag{14}$$

and the stiffness of the fluid column in the cylinder by this equation

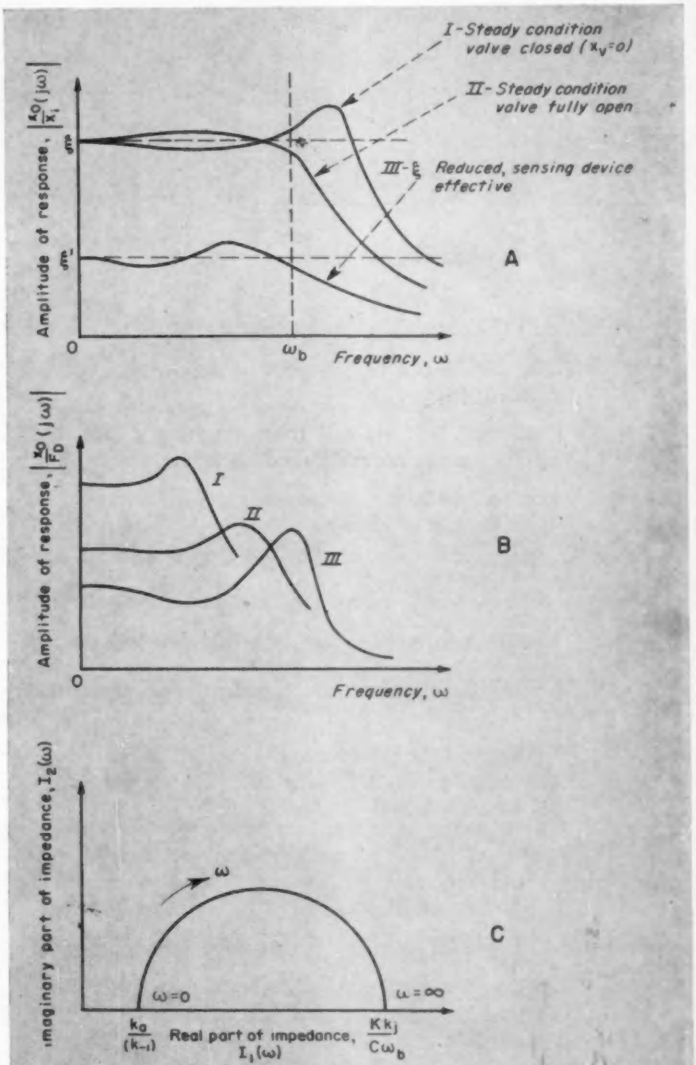
$$k_j = \frac{A^2 N}{V} \tag{15}$$

Substituting these in Equation (10) gives

$$\frac{x_o}{x_i}(p) = \frac{\xi + \dfrac{l}{l_1}\dfrac{L_2}{L}\dfrac{p}{K}}{1 + d + g} \tag{16}$$

$$d = \left(\frac{L_1 + L_2}{L}\right)\frac{l}{l_1}\frac{p}{K}$$

$$g = (1-\xi)\frac{(R-1)}{R}Z_o\left[\frac{l}{l_1}\left(\frac{1}{k_v} + \frac{p}{Kk_j}\right) + \frac{l_2}{l_1}\frac{A_p}{A}\frac{1}{k_p}\right]$$



Frequency response curves for various transfer functions. Only amplitude curves are drawn since phase relations are unimportant in power controls. FIG. 8

For further simplification, the denominator can be separated into components. The first two terms represent a simple lag, while the terms in the brackets are respectively the contributions caused by compliance in the control and the compliance of the sensing element. It is usually the compliance in the control that represents the greatest destabilizing factor.

By introducing new parameters it is possible to rewrite the transfer function in a shorter and more convenient form. In the steady-state condition, when the output load includes an aerodynamic spring force and when the displacement is such that

$$k_a x_o > \overline{F_o}$$

the follow-up ratio can be reduced to a value

$$\xi' = \frac{\xi}{k}$$

where k is a constant numerically greater than unity. Therefore, in a steady-state condition.

$$\xi' = \frac{\xi}{k} = \frac{\xi}{1 + (1 - \xi)\frac{(R-1)}{R} k_a\left[\frac{l}{l_1}\frac{1}{k_v} + \frac{l_2}{l_1}\frac{A_p}{A}\frac{1}{k_p}\right]}$$

From which it follows that

$$(1 - \xi)\frac{(R-1)}{R}\left[\frac{l}{l_1}\frac{1}{k_v} + \frac{l_2}{l_1}\frac{A_p}{A}\frac{1}{k_p}\right] = \frac{(k-1)}{k_a} \tag{17}$$

The bandwidth of the control depends largely on the quantity

$$\left(\frac{L_1 + L_2}{L}\frac{l}{l_1}\frac{1}{K}\right)$$

and the following expression gives an approximate value for the bandwidth.

$$\omega_b = \left[\frac{L}{L_1 + L_2}\frac{l_1}{l}K\right] \tag{18}$$

Finally, a constant C can be introduced so that

$$C = \left[(1 - \xi)\frac{(R-1)}{R}\frac{l}{l_1}\right] \tag{19}$$

Substituting Equations 17, 18 and 19 into Equation 16 gives the following simplified expression

$$\frac{x_o}{x_i}(p) = \frac{\xi + \frac{p}{R\omega_b}}{1 + \frac{p}{\omega_b} + \frac{CZ_o p}{Kk_j} + (k-1)\frac{Z_o}{k_a}} \tag{20}$$

With similar notation it can be shown that

$$\frac{x_o}{F_D}(p) = \frac{\frac{Cp}{Kk_j} + \frac{(k-1)}{k_a}}{1 + \frac{p}{\omega_b} + \frac{CZ_o p}{Kk_j} + (k-1)\frac{Z_o}{k_a}} \tag{21}$$

The real and imaginary parts of the impedance (required for flutter calculations) are given respectively by the following equations

$$I_1(\omega) = \frac{\frac{(k-1)}{k_a} + \frac{C\omega^2}{Kk_j\omega_b}}{\left[\frac{(k-1)^2}{k_a^2} + \left(\frac{C\omega}{Kk_j}\right)^2\right]} \tag{22}$$

$$I_2(\omega) = \frac{j\omega\left[\frac{(k-1)}{k_a\omega_b} - \frac{C}{Kk_j}\right]}{\left[\frac{(k-1)^2}{k_a^2} + \left(\frac{C\omega}{Kk_j}\right)^2\right]} \tag{23}$$

As previously stated, the critical stability condition is encountered on the ground when the output load consists only of an inertia force. This can be represented by

$$Z_o = Mp^2$$

Under this condition it is unlikely that the preload in the sensing device can be overcome. This is equivalent to putting k_p equal to infinity in the previous equations and leads to the relation

$$\frac{x_o}{x_i}(p) = \frac{\xi + \frac{p}{R\omega_b}}{1 + \frac{p}{\omega_b} + \frac{CMp^2}{k_v} + \frac{CMp^3}{Kk_j}} \tag{24}$$

Equations 21, 22 and 23 will be modified in a similar manner.

The relationship between input load and input displacement under dynamic conditions is

$$\frac{F_i}{x_i}(p) = \frac{1}{R}\left(\frac{F_D}{x_o}(p) + Z_o\right)\frac{x_o}{x_i}(p)$$

$$\frac{F_i}{x_i}(p) = \frac{1}{R}\left[\frac{1 + \frac{p}{\omega_b}}{\frac{(k-1)}{k_a} + \frac{Cp}{Kk_j}}\right]\frac{x_o}{x_i}(p) \tag{25}$$

Figure 8 shows frequency response curves for the above transfer functions. A series of such curves can be drawn for values of K and k_v corresponding to each steady-state condition. Then the system parameters, particularly the flow charactertistics of the valve, can be adjusted to give over-all satisfactory control performance.

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BASIC BOOKS FOR YOUR

III—COMPUTERS AND NUMERICAL ANALYSIS

Control Engineering Library

These are the books which tell of the development of computing machines, the principles upon which they operate, and the mathematical techniques which make them useful tools for industry today

THOMAS J. HIGGINS, University of Wisconsin

Analog and digital computers are calculating tools essential to the control engineer concerned with design of a modern complex control system, to the industrial engineer striving to realize in practice the potentialities stemming from high-speed data-processing and operations research, and to the systems engineer utilizing cybernetic and information theory. This article evaluates those books which afford rapid mastery of basic knowledge underlying the construction, operation, potentialities and specific uses of these computing devices. The associated domains of economic dynamics, operations research, cybernetics and information theory, which have opened new vistas of engineering and industrial accomplishment, will be covered next month.

These books divide naturally into four groups:

- Those concerned directly with analog and digital computers;
- Those which afford a basic knowledge of the different phases of numerical analysis underlying effective use of modern computers;
- Those concerned with automation and the dynamics of modern enterprise;
- Those concerned with cybernetic and information theory, which provide common bases linking modern control theory, communication current theory, and neural behavior theory.

COMPUTERS

An excellent purview of the rapid development of computing facilities made available for industrial use during the last several decades is afforded by scan of the book by Horsburgh[1] (1914) on one hand, and those by Meyer zur Capellan[2,3] (1949, 1952) and Hartree[4] (1949) on the other. The first author details the yet limited means available three hundred years after the development of the first major calculating aid, Naperian logarithms. The latter authors both evidence the rapid development in the subsequent four decades and provide an excellent account of the basic theory, construction and use of modern American and European calculating tools: slide-rules, desk calculators, equations and root solvers, Fourier analyzers and synthesizers, planimeters and other desk calculators, mechanical and electronic differential analyzers and integral convoluters, high-speed automatic digital computers, and punched-card equipments. The latter books well complement each other: Hartree is concerned primarily—but not wholly—with the larger computers such as differential analyzers, whereas Meyer zur Capellan concentrates attention on numerous individually-operated mechanical devices. In particular, the latter's second book is replete with detailed illustrative solutions which well evidence application of the devices discussed therein.

ANALOG MACHINES

Much large-scale computation or simulation incident to modern control engineering is done analogically. In so computing or simulating one follows Maxwell's dictum that "The similarity which constitutes the analogy is not between the phenomena themselves, but between the [mathematical] relations of these phenomena." Accordingly, successful analog computation hinges on being able to obtain a readily-manipulated physical system whose equations of operation are such that the parameters of the analog system can be identified in one-to-one correspondence with the parameters describing the system under study. In such case, numerical values obtained through manipulation of the analog system afford the desired numerical values pertinent to the system under study. A large part of analogical computation is now effected electroanalogically because of the flexibility of performance, ease of control, accuracy of solution, and other advantages incident to electrical systems. In such fact, a thorough knowledge of electroanalogic theory is of almost paramount importance to the well-trained control engineer.

The most exhaustive account of the fundamental bases of electroanalogic computation is still that encompassed in the MS thesis by Freymodsson[5] (1947). More readily available, but quite limited accounts of electroanalogic theory are encompassed in the books by Gehlshöj[6], Olson[7], and Hecht[8], The recent excellent book by Soroka[9] advances not only a good account of basic theory, but also the details of construction and operation of numerous kinds of analogic computers. A good complement thereof is to be found in Murray's text.[10]

Among the most widely-used tools for effecting analogic solution are mechanical and electronic differential analyzers. Until recently, differential analyzers, which stem from Lord Kelvin's tidal harmonic analyzer[11], were large and costly machines, hence found limited use as an engineering calculating aid. Recently, however, smaller medium-priced machines such as the Nordsieck mechanical differential analyzer have opened the way to more general use of these devices in engineering practice. The control engineer will therefore find the good, but short accounts of mechanical differential analyzers advanced in particularly the books by Soroka and Hartree (who built the first modern mechanical differential analyzer in Great Britain, largely of Mecanno parts!) of interest. A more detailed account of the basic theory and details of particular machines is advanced by Crank[12].

In much design work, particularly in preliminary stages, speed of computation, rather than extreme accuracy, is the desideratum. For such purpose the electronic differential analyzer provides a facile tool: as is evidenced by the many different makes which are now being marketed. However, the basic principles of all are much the same and can be gleaned from the texts by Soroka, Hartree and others. A more detailed coverage is provided in the books by Korn and Korn[13] and by Raymond[14]. These well complement each other: the former leans heavily on details of construction and illustration through discussion of American machines; the latter advances a good body of additional theory and illustration of many European computers.

DIGITAL COMPUTERS

An excellent coverage of digital computing is provided by conjunction of the book by Booth and Booth[15] and that edited by Bowden.[16] The latter comprises 26 chapters, each written by a well-known specialist in the field. Fundamental information as to basic principles and circuits; conjunction of these to yield a digital computer; and details of construction, programming, performance and maintenance of machines are supplemented by excellent accounts of the historical development (of digital computing in general and of certain machines in particular) and by detailed descriptions of major British machines. Accounts of present and projected applications to the solution of problems in logistics, industry, commerce, government and recreation round out the text.

Thus, Chapter I comprises an excellent account of the life and work of Charles Babbage,[17] the pio-

neer of large-scale automatic digital computing. Chapters 2 to 5 encompass basic components, interconnection into a computer, and performance, maintenance and programming. Chapters 6 to 13 advance detailed account of the principal British digital calculating machines; Chapter 14, a brief sketch of American machines; Chapters 15 to 24, applications in various fields of endeavor; Chapter 25, an outline of logical and recreational machines; and Chapter 26, discussion of a machine's "capacity to think." The especial values of this fine work for the control engineer have been well-summarized by a recent reviewer: "This book can be thoroughly recommended because it gives us a clear over-all picture of how these machines work, when we should use them, and when we would be wiser to call in the human expert. Sufficient further detail concerning basic circuits, individual machines, etc., is also available for the minority who require it" (Wireless Engineer, Dec. 1953, pp. 318-19).

In that Bowden's book is a compendium of highly descriptive articles, especially meritorious in the excellent history of digital computing to-date, with a prime emphasis on *computers*, it is well-complemented by Booth and Booth's work, which is a textbook prepared for self-study or class instruction in digital *computation*. Chapters 1 to 3 comprise a concise review of the development of digital computers, buttressed by account of special machines now in use; Chapter 4, account of fundamental mechanical and electronic components and intraconnection thereof to form a working machine; and Chapters 5 to 17 detail coding and programming of problems for solution and account of various applications of digital computers. As in all textbooks, certain shortcomings are evident; but nonetheless, Booth and Booth's is the best existing textbook on automatic digital computation.

The content of the two books just discussed is, for the particular reasons noted, well-complemented by the following works:

▶ "A Survey of Automatic Digital Computers"[18]—which gives full technical details on 98 computers, based on information collected to February, 1953.

▶ "Review of Electronic Digital Computers"[19]—which advances descriptions of ten large-scale computers of varying design and performance; details operating and component experience on some of these calculators; and both sums the state of computer development in 1951 and indicates future possibilities of use.

▶ "Proceedings of a Symposium on Large-Scale Digital Calculating Machinery"[20]—which is of interest for the excellent account of the art towards the end of the first stages of development, in 1947.

▶ "High-Speed Computing Devices"[21] — which comprises "discussion of the devices and electric circuits that can be incorporated into computing machines, illustration of integration of technique and components into complete systems being approached by account of a few American machines."

▶ "Synthesis of Electronic Computing and Control Circuits"[22]—which somewhat complements the immediately-preceding text.

▶ "Digital Differential Analyzers" by Forbes,[23] which comprises a good, medium-level exposition of digital differential analyzers and how to compute with them.

GENERAL CONTENT

In the large, the above-mentioned books are of a highly-technical nature. The control engineer who seeks a more cursory account—descriptive of machines, their possibilities, and of the "philosophy" underlying construction and use of them—is afforded such in:

▶ Berkeley's[24] "Giant Brains: or Machines That Think"—which provides a well-rounded account of analog, digital, and recreational machines, encompassing sufficient detail so as to make clear how they work, what they can do in practice, and prediction of future uses and economic consequences.

▶ Couffignal's[25] Les Grandes Machines Mathématiques"—which is somewhat rooted in his earlier "Les Machines à Calculer, Leurs Principes, Leur Evolution"[26] and whose contents are as indicated in their titles.

▶ Couffignal's[27] "Les Machines á Penser"—a recent work which provides a "philosophical" and logical complement to the preceding books.

▶ "Les Machines à Calculer et la Pénsée Humaine"[28]—which comprises 38 papers presented at the 1953 International Conference on Computing Machines held in Paris. Of these, 15 are devoted to account of large-scale analog and digital computers, including account of a number of unique European machines; 8 to problems of mathematic and applied science pertinent to these machines; and 15 to logical, biological and neural aspects of calculation.

For the most part, only general details of operation of specific types of computers are encompassed in the above-stated texts. Specific detail pertinent to the most efficacious operation of a particular machine is, naturally, only to be gained by first-hand experience. However, of certain of the more commonly-used machines, a considerable amount of pertinent information can yet be garnered from the above-mentioned books; or from texts[29,30] particularly concerned with programming and operation; or—best— from manuals, too numerous to detail, prepared for a particular machine by its manufacturer,[31,32] or by an interested user—as exemplified by the manuals prepared by Gruenberger[33,34] for use with IBM punched card equipments.

The present ready availability of high-speed automatic digital computers to the control engineer naturally entails a corresponding need of familiarizing himself with modern methods of numerical analysis pertinent to most effective phrasing and solution of

his problems therewith. For the most part, control work entails solution of sets of linear algebraic equations; various algebraic work such as extracting roots of equations, or affecting polynomial and trigonometric or interpolation; solving boundary value problems characterized by integral equations or by ordinary or partial differential equations; obtaining characteristic frequencies and modes; and effecting statistical calculation. In recent years a number of books covering the corresponding pertinent theory, with particular recognition of the values of modern computer calculation, have been written. Of these, the control engineer will find the following of especial value and use—for the reasons detailed.

NUMERICAL ANALYSIS

▶ "Linear Computations" by Dwyer[35]—provides a good account of the general problem of affecting numerical solution of sets of simultaneous linear equations, with accompanying excellent pertinent detail on determinants and matrices.

▶ "Linear Equations in Applied Mechanics" by Purday[36] comprises an exceptionally fine book for the practicing engineer who must rely on self-study. Ready grasp of the material discussed is facilitated by advance of many detailed numerical examples and relegation of rigorous proofs of theory to stated references. Thus, an engineer with only the usual elementary knowledge of calculus will find herein a good account of the basic aspects of linear algebraic equations, ordinary and partial differential equations, and integral equations conjoined with account of the auxiliary tools of matrices, invariants, vectors, tensors, conjugate and orthogonal functions, and infinite series—the whole written with emphasis on the numerical aspects of numerical calculation and tied together through the use of matrix notation throughout the text.

▶ "Methoden der Praktischen Analysis" by Willers[37] gives an excellent coverage of numeric interpolation, approximate integration of functions and differential equations, curve-fitting, and methods of obtaining the roots of equations. Much of this material is available in the translation "Practical Analysis"[38] of the first German edition.

▶ "Numerical Calculus: Approximations, Interpolations, Finite Differences, Numerical Integrations and Curve Fitting" by Milne[39] comprises the content evidenced in the title, written with appreciation of the potentialities of modern large-scale calculating facilities.

▶ "Numerical Analysis" by Hartree[40] is couched in somewhat the same vein as Milne's text, algebraic and analytic work being limited to methods particularly useful for numerical calculation (with stress on the importance and means of checking) and with a prime emphasis perhaps on methods suitable to hand calculators. Automatic digital computation receives rather limited discussion, primarily through a chapter on certain basic aspects of programming.

▶ "Principles of Numerical Analysis" by Householder,[41] especially bent towards appreciation of the values of high-speed digital computation, concentrates on solution of finite systems of linear and nonlinear equations and on the approximate representation of functions. This aim is well achieved through chapters on error and the art of computations; matrices and linear equations; nonlinear equations and systems thereof; a good account of effective means of extracting the roots of polynomial equations and of characteristic equations; interpolation; approximate numerical integration and differentiation; and a short chapter on the Monte Carlo method. Particular effort is made to encompass the often-slighted task of providing insight to the art of actually effecting numerical calculation.

▶ "Techniques de Calcul Numérique à l'Usage des Mathématiciens, Astronomes, Physcients et Ingénieurs" by Mineur[42] is an exhaustive work, written expressly for the engineer and applied scientist. It is a valuable complement to both Householder's book and the well-known, older, more formal, but yet highly-useful texts by Scarborough[43] and by Whittaker and Robinson.[44]

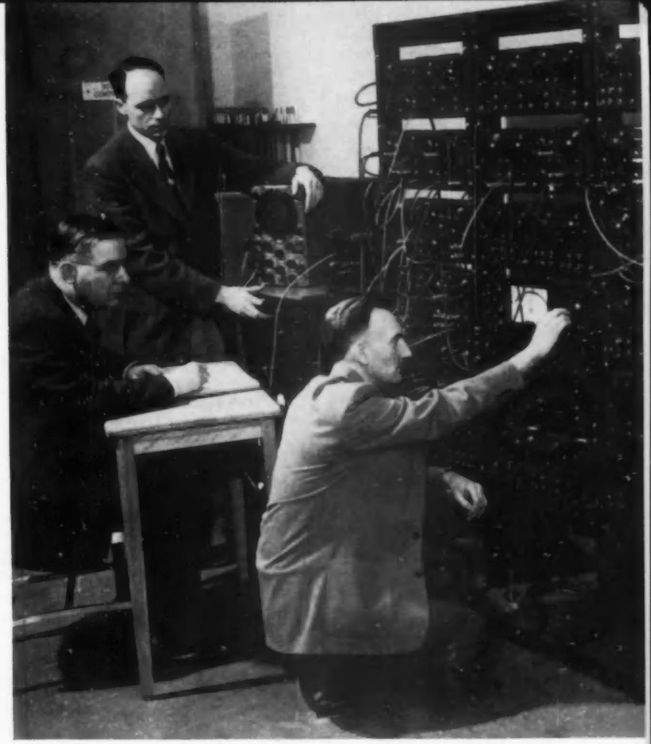
The special field of the numerical solution of differential equations is well-encompassed in the books by Levy and Baggott[45] (now somewhat dated), the excellent modern treatment by Milne,[46] and the exhaustively detailed books by Collatz.[47-49] The latter's treatment of eigenvalue (or characteristic frequency) problems is well-complemented by the recently-issued collection of papers edited by Page and Taussky,[50] wherein the values of high-speed digital computation are admirably evidenced. Finally, the unparalleled text by Kryloff,[51] detailing many powerful approximate and variational procedures developed by himself and Russian colleagues, comprises a mine of information and procedures, well-suited to digital computation and particularly effective for solving control systems with distributed parameters.

Many powerful schemes of computation particularly suited to automatic digital computer calculation are rooted in the calculus of finite differences. The control engineer desirous of gaining a basic knowledge of this field will find a particularly lucid text in the recent book by Richardson.[52] With the basic knowledge gained therefrom, he can then—as necessary—turn with confidence to the more advanced texts by Boole[53] (now dated), Nörlund[54] (a rigorous mathematical text), Milne-Thomson[55] (written with respect for the applied point of view), and Jordan[56] (whose book I have found of especial value in the study of generating functions theory, the prime analytical tool used in analyzing and synthesizing sampled-data control systems). The particular topic of linear difference equations is admirably treated by Batchelder[57] and Fort.[58] Finally, difference-differential equations, a subject of great current

interest in connection with the theory of systems involving time delay, is treated at length in the recent texts by Myshkis,[59] Bellman[60, 61] and Pinney.[62]

Richardson's text[52] provides a firm foundation for a specialized study of the powerful approximate procedure of "relaxation", a method of great utility in solving the partial differential equations encountered in control systems involving distributed parameters. The engineer desirous of gaining mastery of relaxation techniques ought, perhaps, first study one of the recent excellent texts by Allen[63] or by Shaw,[64] before turning to the well-documented, but not-easily read, texts by Southwell,[65, 66] the inventor of relaxation technique. Also, the books by Milne,[46] Collatz,[47-49] and Mikeladze[67] encompass good account of relaxation and other numeric finite-difference procedures applicable to the solution of problems encountered in some of the more advanced aspects of control engineering.

In conclusion, it is to be remarked that whereas the above-cited works provide general information, background, and technique, a vast amount of specific computer information is to be found in the proceedings of specially-sponsored meetings.[16, 19, 20, 28, 68] In particular, the truly-interested control or computer engineer must follow faithfully the Proceedings[69, 70] of the annual Eastern and Western Computer Conferences sponsored jointly by the IRE—AIEE—ACM; the Proceedings[71] of the Association for Computing Machinery; special issues of regular journals such as the October 1953 issue[72] of the IRE Proceedings (which comprises 41 papers devoted to electronic computers); and, of course, regular journals devoted to computers, such as the Transactions of the IRE Professional Group on Electronic Computers. In fact, in a field advancing as rapidly as the computer field, books and proceedings of symposia can provide only background information. The current state of the art is evidenced in the regular periodical literature.



Professor Higgins, shown here at far left with his colleagues in the computer lab at the University of Wisconsin, will continue his series next month by reviewing the books which deal with business dynamics, data-processing, operations research, cybernetics, and information theory. The series will conclude in March with a review of the periodicals of interest to the control engineer.

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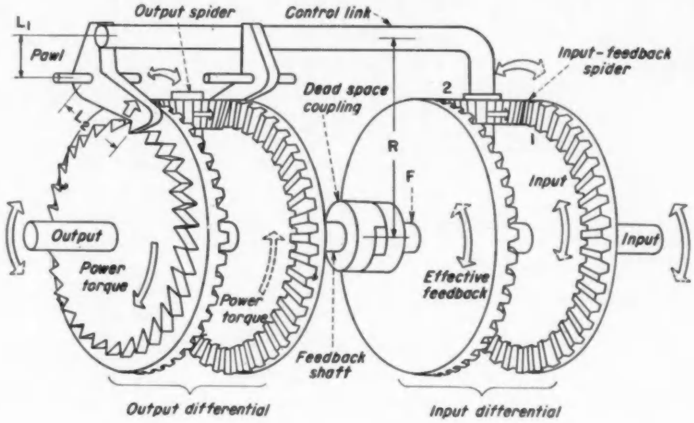


Clockwork Torque Amplifier Rotates Discretely

This amplifier drains no standby power. Its digital output—average error: zero—suits it for turning rotary switches or for converting dials to counters

RAYMOND N. AUGER

Most torque amplifiers demand a continuous source of external energy. One exception is the spring-powered amplifier shown. Its value lies in possible application to mobile installations that have limited or unreliable power sources, or where discrete-unit motion is needed. Because of conventional clock or watch manufacturing techniques, accuracy, low, cost, and small size can be combined.

WHERE IT CAN BE USED

Efficient use of input energy, and no standby drain at all, result from one-pulse solenoid winding, as in some automobile clocks. Spring-stored energy also carries the amplifier through central power lapses. For mobile or remote applications, hand winding might be applicable.

As for digital characteristics, the output shaft always stops at points corresponding to ratchet teeth. Therefore it can rotate switches to exact positions, make counter show only full numerals, and position analog components to precise points. Light-duty valves can be operated directly by pressure or temperature sensers.

For converting pointer indicators, especially multi-revolution dials, to counter indicators, without greatly increasing cost or bulk, this amplifier might be an attractive standard component for many meter makers.

HOW IT WORKS

It has two basic sections: an input, or error differential; and an output, or power differential. Joining them is a control link and feedback shaft.

The input differential receives both input and output signals. Its spider is rotated to the right or left of a zero position according to the error between input and output. Each side of the output differential is spring powered in an opposite direction, and restrained by a pawl. The error signal, represented by the off-center displacement of the input spider, lifts the proper pawl to release the direction of rotation in the output differential which, through feedback to the input differential, returns the input spider to its central position. At this point the input spider allows the lifted pawl to reengage and halt output rotation. A constant rotation of the input shaft results in a series of starts and stops by the output shaft—that is, each time output catches up with input.

SOME DESIGN FACTS

Mainspring winding without interruption of operation requires two springs in series with re-wind torque applied between them. A quick way to estimate basic dimensions is found in $\frac{E}{360} \times R = D\frac{L_2}{L_1}$: E is the unit of minimum output rotation in degrees; R is the radius of the control link's point of contact with a pawl measured to the center-line of the input differential; D is the distance the face of the pawl must travel to move from a position of clearance to full interference with the ratchet teeth; and $\frac{L_2}{L_1}$ represents the pawl leverage.

Assuming that the system has no backlash, it will have zero error between input and output only at those values of input corresponding to "trip-points" or ratchet teeth at the output differential. As the spacing of these points as measured in degrees at the output is E, with a steadily rotating input, the output will average an error of half the distance between trip-points, or $E/2$ = average steady state error. The maximum offset is E. Now let the output shaft be advanced $E/2$ ahead of the input for both directions of rotation, and the average error becomes zero, with the maximum error plus or minus $E/2$.

But since an input motion E is required to trip the output, a change of rotation will result in an error of always $E + E/2$ just before tripping rotation in the new direction, and the return of the average error to zero.

However, the system is not without backlash. The lost motion in the input differential, meshes 1 and 2 (see cut) should be compensated for by advancing the output by an equivalent amount B. This will also add to the change-of-direction dead zone which will now become $E + E/2 + B$. Due to the dead-space coupling, the output "overshoots" this much to arrive at its proper value. It is essential that the static friction at point F be greater than the average input torque, lest this dead space be occupied by the input signal. As for the output differential, since each side of it can drive and be driven in only one direction, backlash is of no significance there.

Radiation Pyrometer Sensitive to Freezing Waves

FRITZ LIENEWEG AND ALFRED SCHALLER, Siemens & Halske Aktiengesellschaft

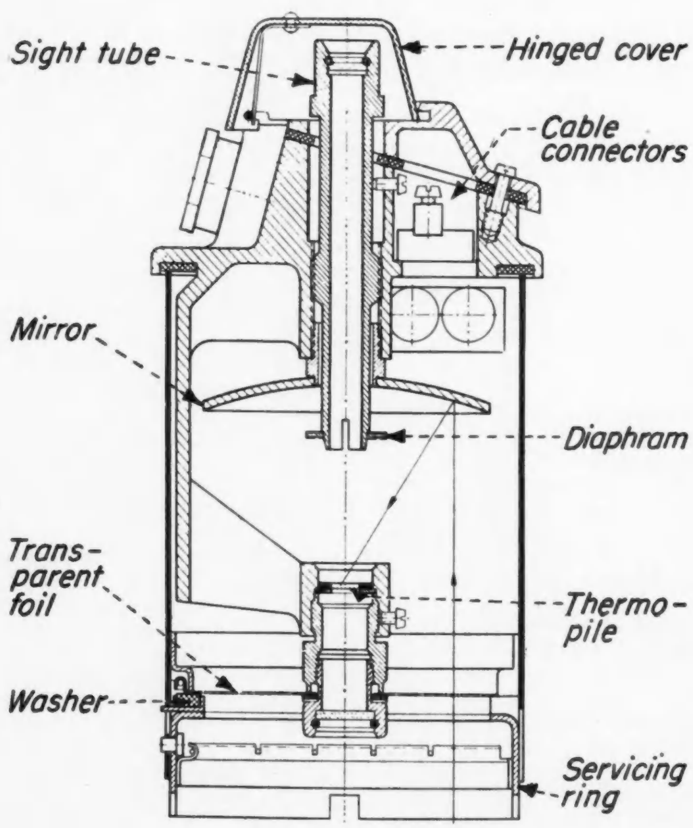
This German instrument is the first of its kind that is sensitive at room temperature. It can even take below-room-temperature readings in frozen food plants

The major difficulty in measuring surface temperatures, especially of moving objects, lies in the possibility of the measuring device itself creating thermal variations. One example is the heat created by the friction of a contact-type thermometer on a moving film or strip of material. Radiation pyrometers, however, need only radiated energy for their operation, and so escape this difficulty. Although, in theory, the radiator should be a black body with an emission index of 1, calculations can be made to circumvent this difficulty so that pyrometers are used successfully with all more or less dark bodies.

With the exception of metals, the radiation of all materials increases with the radiation frequency. In the extreme infra-red regions virtually all surfaces may be treated as black radiators, and pyrometers sensitive to this region will be accurate with a wide variety of surface colors and finishes. Also, since different temperatures radiate at different frequencies, a pyrometer sensitive to the high infra-red regions will be more sensitive to variations in the low-frequency range. An illustration of this principle occurs when one tunes into a radio program and is on the "fringe" of the proper setting. The station selector then is also a very sensitive control of volume.

Since, in all pyrometers, lenses or mirrors focus radiations on the sensing element, the distance of a pyrometer from the radiating surface can be varied. Because glass and quartz tend to absorb heat radiations in the lower frequencies, the use of pyrometers with lens systems is limited to measurements of temperatures greater than 800 deg C. If a high-gain amplifier is used with a lens pyrometer, temperatures as low as 250 deg C can be measured.

The pyrometer shown here uses a concave mirror for focusing, in the style of the Féry instrument. The basic difference between the two is that the Ardonox has a thin plastic foil that passes all required heat frequencies yet does not allow currents of air or settling dust to disturb its performance. The mounting for this foil is arranged to allow easy replacement.



Cross-section: The hinged cap in rear allows accurate sighting through tube. FIG. 1

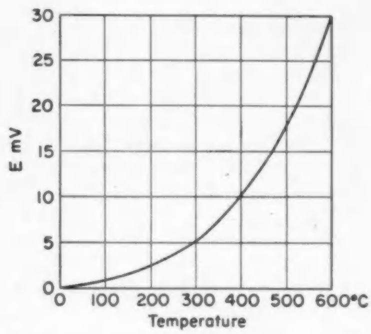
RADIATION RECEIVERS

The sensing element in a pyrometer may be a thermocouple, photocell, or thermistor. Photoelements are not sensitive enough to infra-red rays. A chrome nickel-constantine couple is used in the Ardonox because of its sensitivity to these rays and because of its overall stability. Ideally, the rate of surface radiation of the sensing element should equal the amount lost by conduction through its supports. In this way it will store, and hence be sensitive to small radiation varia-

tions. But in order to increase this unit's responsiveness, it has been designed so that the rate of loss through conduction is greater than that lost through radiation. This characteristic requires a compensation at higher temperatures. Also, the temperature of the housing will play a large part in the rate at which heat is conducted from the thermocouple. The influence of housing temperature is especially great below 600 deg C.

CONSTRUCTION

The plastic foil which seals the face of the instrument is only .1 mm thick, and even at room temperatures absorbs only 30 per cent of incoming rays. However, because it will withstand temperatures of only 70 deg., the housing must be kept below 60 deg. C. The aluminum coated mirror is covered with a layer of quartz as a protection against corrosion. A bridge circuit employing a thermistor is used for case temperature compensation, and another thermistor in parallel with the thermocouple is used to compensate for the increased heat conduction error which occurs at high radiation temperatures. So that the Ardonox can withstand case temperatures of greater than 60 deg C. it is adaptable for both water and air cooling. A sensitive galvnometer can record temperatures directly without need of an amplifier in the range of 20 deg C. and higher. 0 deg C. and higher can be realized with an amplifier, and from 500 deg C. and up the output will be adequate to operate a scribing recorder directly.



Ardonox output curve illustrates its sensitivity at low temperatures. FIG. 2

The response time of the Ardonox is in the range of 2 or 3 sec. Because of its sensitivity to the infra-red region, the Ardonox tends to regard all surfaces, including glass at higher than 500 deg C., as black. However, slight measuring errors will occur in the case of mirror surfaced materials such as polished steel or aluminum.

The rear wall of the Ardonox has a hole on the optical axis, into which the sight tube holding the concave mirror can be screwed. At the front is a cylindrical tube for mounting the thermocouple. Between the concave mirror and the thermocouple is a disc which acts as a diaphragm. Its effect is varied by sliding the sight tube back and forth. The cable connection box is situated in the rear. The protruding part of the sighting tube is protected by a cover. The foil of synthetic material, together with a washer, is placed into the front part of the Ardometer housing and secured by means of a sealing ring. A wide-meshed wire-grid protects the foil.

APPLICATIONS

The instrument is of value in laminating and metal rolling operations where high roller temperature can result in roller breakage. In furnaces and ovens where hot-spots can damage the refractory material, excessive temperatures can be conveniently detected. The radiation pyrometer can be used in foundries to protect sand molds from excessive temperatures in drying ovens. Rubber rolling processes may result in the surface of the rubber being higher than that of the rollers. By means of the Ardonox, top-surface temperatures can be measured to 1 per cent accuracy. In foil, paper or plastic rolling processes, this instrument also has applications. Where more or less transparent material is involved, three or four layers can be presented as to minimize the effect of the backing surface's temperature.

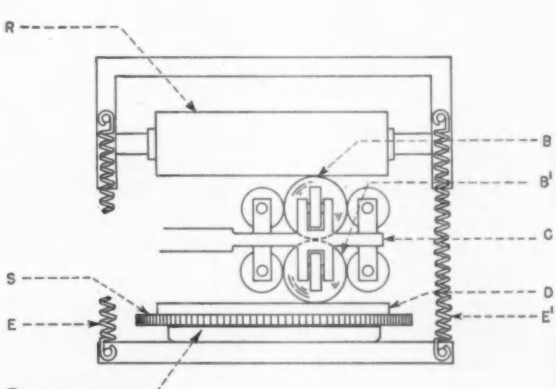
Another type of application for this instrument is the external examination of ovens, hearths, heaters, and conduits for the detection of excessive high temperatures. Breaks in heat can also be found. Below-room-temperature readings can be carried out in frozen food plants or other low-temperature processes.

Mechanical Integrators Control Torque-Speed

LESTER E. KEENE, Anderson-Nichols Co.

Photographic recording of periodic phenomena, including oscilloscope displays, calls for a sensitive and rugged high-speed film transport system. The requirements:

- ▶ Accelerate a 400-foot reel of film to a linear speed of 100 in. per sec. in .3 sec.
- ▶ Maintain speed within plus-or-minus 2 per cent.
- ▶ Hold film tension nearly constant



▶ A disc D rotated by a chain driven sprocket S.
▶ Two balls B and B' held in carriage C.
▶ Driven roller R.
The disc and sprocket assembly mounts on ball thrust bearing T and is driven at a constant speed. FIG. 1

throughout the sequence of acceleration–fixed velocity–deceleration to prevent damage to the film.

The requirements are met in an all-mechanical servomechanism incorporating three ball-and-disc speed changers. The main one regulates speed. Two auxiliaries maintain film tension.

TYPICAL SPEED CHANGER

Figure 1 illustrates the basic speed changer used in this system.

Two balls located between the disc and the driven roller, while free to rotate are held captive in the carriage C by four small rollers placed at 90-degree intervals. The carriage is so supported that it can move radially across the disc from the center to fixed velocity positions. Changing the radial position of the balls varies the driven roller's velocity. The roller develops maximum velocity when the ball carriage is at its maximum radius. Roller velocity gradually reduces to zero as the balls approach the center of the disc.

The driven roller mounts in ball bearings in a hinged cover plate. Springs E and E′ hold the cover plate to the base plate and thus create a large pressure between the driving and driven elements. Because tractive friction is directly proportional to pressure, the rolling point contact moves the load with insignificant slippage. In addition, speed changes are made without shock.

These speed changers are commonly used for continuous integration of two inputs, in which case the direct power transmission is negligible. In other service, up to 2 hp has been transmitted.

CENTRALIZED SPEED CONTROL

Driving energy from the main motor couples through the main speed changer to all succeeding units in the system, including the two auxiliary speed changers, the film supply and takeup reels, and the constant velocity spool that conveys the film through the image plane. In this way, the main speed changer provides centralized control of the complete system. The acceleration and deceleration times for this unit, therefore, limit the acceleration and deceleration of the complete system. It is consequently advisable to hold the acceleration requirements of the system within those of the main drive motor.

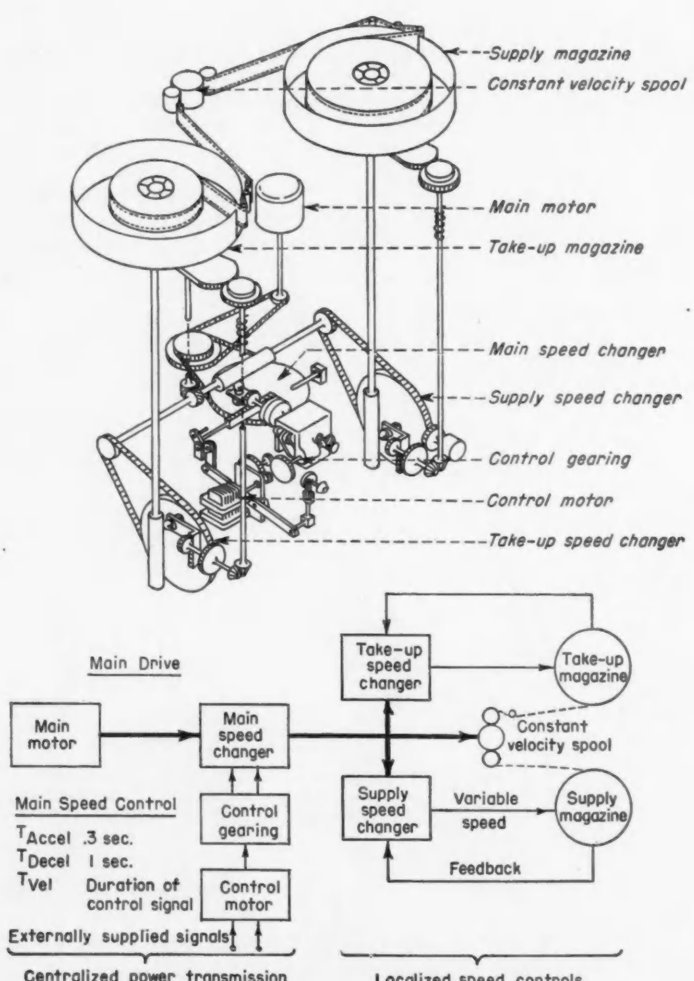
The main speed control is shown in the diagram of Figure 2 by the units labelled Control Gearing and Control Motor. The control motor, turned on by an external switch, drives the ball carriage radially from its initial position at the drive disc's center to a pre-set positive stop in .3 sec. During the constant velocity interval of the cycle, the control motor stalls against the stop. At the end of the constant velocity period, the control motor is reversed and the speed drops to zero in 1 sec.

In case the acceleration time of the main drive motor is too great, the drive disc can be pre-accelerated with the ball carriage at dead center. When the drive motor reaches synchronous speed, the control motor is then turned on.

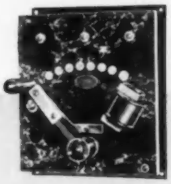
LOCAL REEL CONTROL

Because the film may be distributed on the reels in any ratio, the inertia load on the drive mechanisms is variable. And the angular velocities of the reels are unequal because one reel is taking-up film while the other reel is paying it out. Therefore separate speed changers are necessary to maintain film tension between the supply and take-up reels.

As in the main speed changer, reel velocities are manipulated by radial displacement of the ball carriages on the disc. The linkage that makes the respective carriage displacements responsive to reel tension is represented by the feedback loops in the block



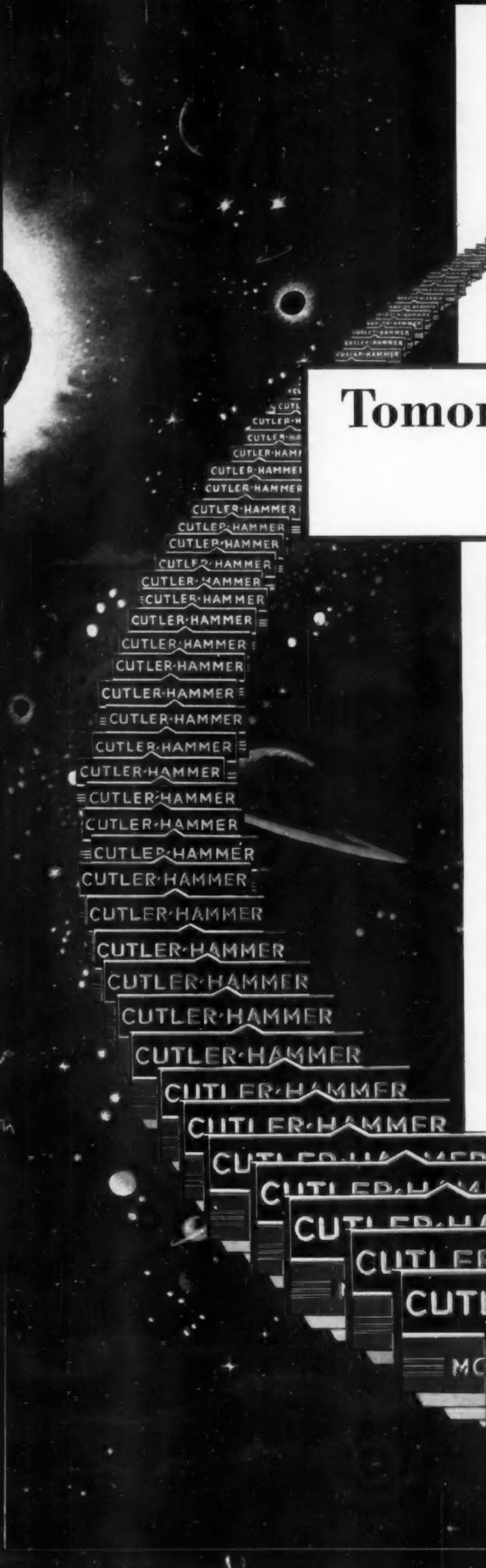
Isometric and functional diagrams of film transport system. FIG. 2



The "Kitty Hawk" of Automation

The very first automatic feature in motor control was the no-voltage release in the Cutler-Hammer Bulletin 10 Starter of 1892. The starter handle was held in the "on" position by an electromagnet and returned automatically to the "off" position whenever the power supply failed. This protected men at machines from sudden unexpected restarting, motors against burn-out due to the inrush of uncontrolled current.

Tomorrow dawned 63 years ago!



New ideas are seldom as new as most people think. Automation is typical. If automation is tomorrow's way of manufacturing, this *tomorrow* dawned 63 years ago with the beginning of automatic electrical control. What is now possible in automation is not the result of sudden discovery but the application of control techniques and equipment developed through *decades* of experience.

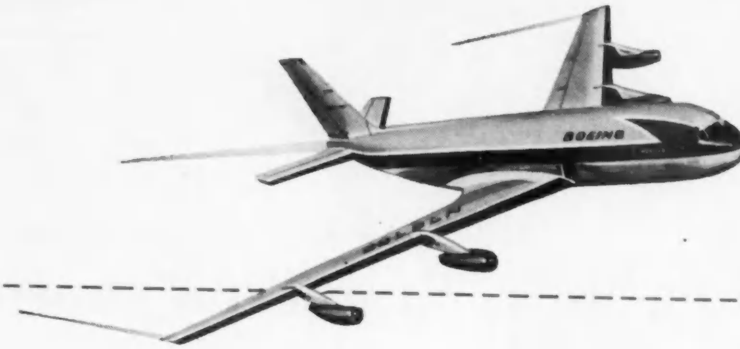
This is an important consideration to anyone interested in automation planning. Automation is always a major project. It requires a large investment in planning and engineering . . . and an outlay for equipment often without precedence in a company's experience. The rewards for success can be momentous. But the penalties for mistakes can be disastrous.

Able management has been quick to realize the safeguards provided by maximum automatic control experience in even the earliest exploratory discussions of automation. As a consequence, Cutler-Hammer engineers and Cutler-Hammer Automatic Control have already helped in turning "visionary" plans into astounding automation realities in such diverse industries as cement, glass, paper, rubber, sugar, steel, textiles and automotive.

If automation is a "must" in your future, now is the time to act to make it a competitive advantage rather than a handicap. It cannot be rushed into being; it always requires a vast amount of skillful planning and ingenious engineering. Invite Cutler-Hammer engineers to participate. Their experience is almost sure to speed your project. It can help you avoid false starts, prevent impractical or needlessly complicated constructions. It may even point the way to unsuspected automation possibilities, as it has for others. Write, or wire CUTLER-HAMMER, Inc., 1467 St. Paul Avenue, Milwaukee 1, Wisconsin.

THESE 5 LEADING AIRCRAFT

BOEING



CONVAIR

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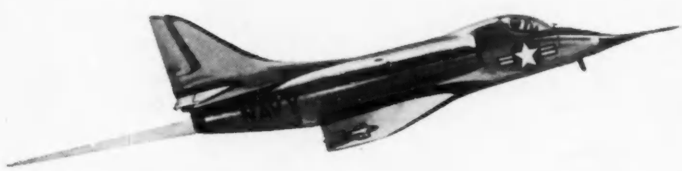

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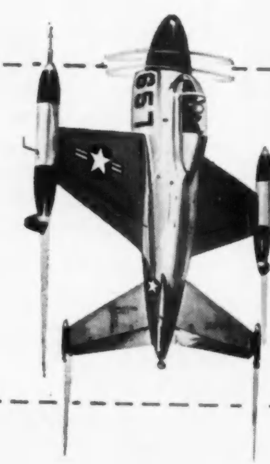


NORTH AMERICAN

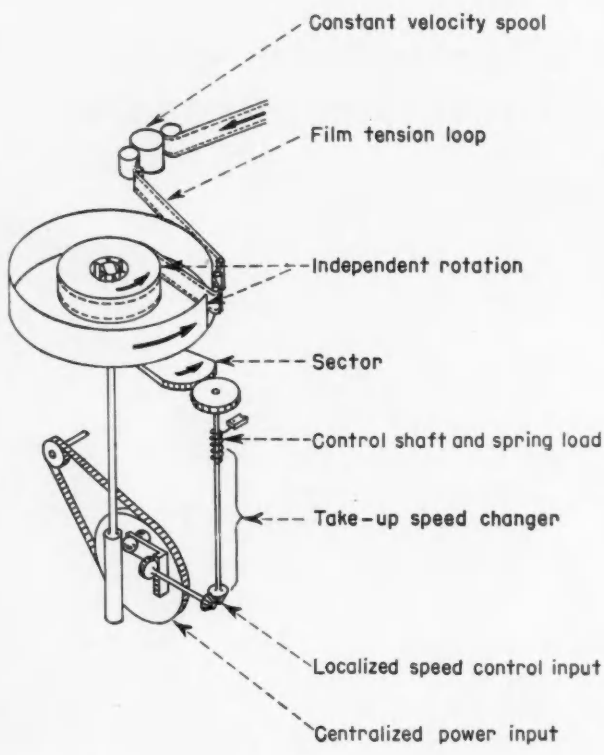
diagram of Figure 2. The sensing linkage controls the infinitely variable output ratio of the speed changers by detecting changes in film tension on either side of the constant velocity spindle. This spindle is driven through a 1:1 coupling at the main speed changer output shaft.

Figure 3 illustrates the method in which sensing of film tension is used as the control intelligence for manipulating reel speeds. Space optimization precluded the use of control arms in this design. Consequently, the film magazines themselves were made to act as sensing mechanisms. The magazines are portable, quickly interchangeable, light-tight, protective receptacles for unexposed or undeveloped film rolls. The magazines can rotate approximately 30 deg. independently of the high-speed continuous rotation of the film reel within the magazine. An adapter mounted on ball-bearings in the magazine base assures independent rotation. When the magazine is dropped into position, the adapter keys directly to the speed changer output shaft and couples to the driving element within the magazine.

The positions of the magazines at either end of their arcs of rotation represent extreme reel conditions and corresponding velocities. For example, consider the takeup reel. As the system cycle progresses, the load is shifted onto this reel. The magnitude of the load is related to the diameter of the accumulating film roll at any given instant. The diameter in turn can be related to the required peripheral velocity. Thus, if diameter were sensed, the ball carriage could be moved mechanically to the appropriate position on the rotating drive disc. However, direct diameter sensing is not necessary, since the speed changer mechanisms make it possible to simplify the sensing operation.

Before the cycle is started, the takeup reel is empty except for a thread lead. The magazine is spring-loaded toward the position of maximum speed. During the operating cycle the velocity of the reel will vary from maximum to minimum in accordance with the variance of the load from small to large diameter. The film tension is sensed and maintained at a point between the magazine and the constant velocity spool. As the diameter of the takeup reel steadily increases, the takeup rate tends to increase. Tension tends to increase correspondingly, causing the magazine to rotate in compensation. This rotation of the magazine is, in effect, mechanical conversion of the feedback signal to the control mechanism of the takeup speed changer. A gear sector moving with the magazine engages a pinion on the control shaft. The control shaft is under the tension of a torsion spring which is the constant load on the magazine. The control shaft, in turn geared to the ball carriage of the speed changer, thus supplies the localized speed manipulating force. Action at supply magazine is identical but opposite.

Test cycling of this system under controlled conditions was carried out for over 100.000 cycles. At no time was the stability of the system affected or the tension balance appreciably altered from its pre-set level.



Local tension control at takeup reel manipulates ball carriage of speed changer. FIG. 3

ADDITIONAL FEATURES

The complete design for this film transport system includes special electrical circuits to stop the motors. This eliminates excessive wear on the main driving disc and avoids the necessity for a special hardened center insert. Means are provided for automatic identification of each film exposure, the device projecting a serial number and the date and time of the film exposure. In the event of film breakage and loss of tension, the takeup reel immediately snaps to a cutoff position at which the control motor is reversed, halting the system.

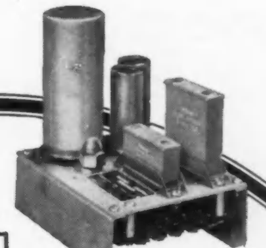
FEEDBACK FANCY

Needed: A simple hand-set speed-zone indicator for motorists.

Suggested: A capacitance pickup on the speedometer needle which would trigger a sizeable "SLOW DOWN" on the dashboard when car exceeds the speed limit.

TYPE 2003
Same as Type 2007 (at right) except Tube 12AT7 and 5 pigtail components are external.

TYPE 2007, BASIC UNIT
Contains shock-mounted fork, double triode and all circuitry. Output, 400 or 500 cycles. Accuracy ± 1 part in 50,000. Octal base container, 1½" x 4½". Weight, 10 oz. Power required, 75 to 200 V.-D.C. at 1 to 5 m.a. and 6.3 V. at 300 m.a. Designed for MIL equipment.



TYPE 2001-2, BASIC UNIT
Frequencies, 200 to 3000 cycles. Dividers and multipliers available for lower and higher frequencies. Output, 6 V.—JAN construction.

TYPE 2005, UTILITY
Provides 10 Watts at 110 V. Precision frequencies from 50 to 500 cycles. Input power, 50 to 500 cycles, 45 Watts.

TYPE 2121-A, LAB. STANDARD
Outputs, 60 cycles, 0-110 Volts, 10 watts; 120-240 cy. impulses. Input, 50-400 cycles, 45 Watts.

TYPE 2111A, POWER UNIT
50 Watt output. 0-110-220 V. at 60 cycles or any frequency 50 to 1000 cycles.

Precision FREQUENCIES

GUARANTEED ACCURACY
1 PART IN 100,000 (.001%)
except where otherwise noted

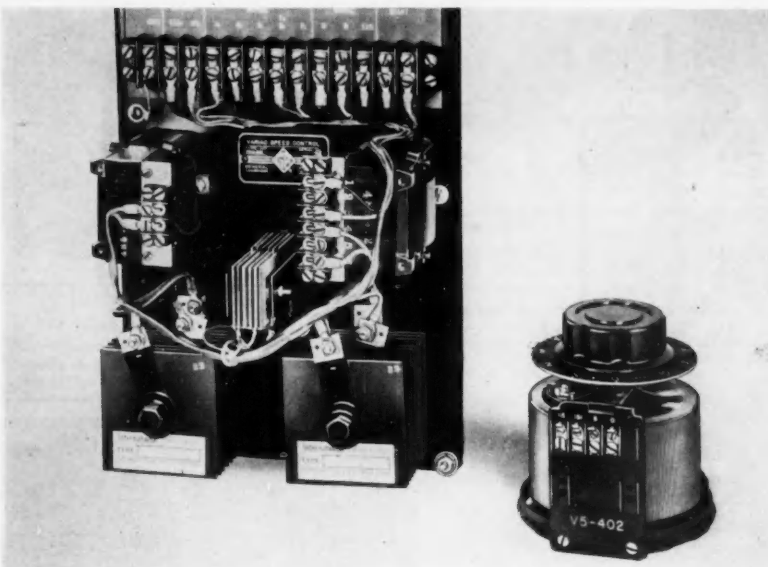
The basis of these frequency standards is an electronically actuated high-precision fork, temperature-compensated and hermetically sealed against barometric changes. The partial list of uses at the right not only suggests the broad range of applications but also proven dependability where there can be no compromise with accuracy. Please request details by Type No. Our engineers are available for advice or cooperation on related problems.

WIDELY USED IN SUCH FIELDS AS
Aviation, Navigation
Ordnance, Ballistics
High Speed Photography
Viscosity Measurement
Fluid Flow
Nuclear Physics, Telemetering
Chemical Reaction
Radiation Counting
Computers
Facsimile
Fire Control
School and Indl. Research Labs.
Accurate Speed Control

American Time Products, Inc.

580 Fifth Avenue ***New York 36, N. Y.***

OPERATING UNDER PATENTS OF WESTERN ELECTRIC COMPANY



LISTING IN GROUPS

1 Stripped Motor Control
2- 5 Motors for Control
6-11 Digits in Control
12 Continuous Blender
13-16 Servos in Control
17-23 Timers & Relays
24-27 Processing Components
28-31 Valves in Control
32 Optical Pyrometer

SOME MOTORS FOR CONTROL →

MOTOR CONTROLS stripped down to take on equipment or system-tailored functions.

Customer demand has caused this manufacturer to develop a line of "stripped-down" models of its standard motor speed controls. The models include the basic components of the original controls but omit the switches, overload protection, and cabinet. As such, what is left are the "sinews" for operating d-c shunt and compound motors from a-c power lines.

The maker claims that motor controls in this form eliminate functions which may not be necessary in the design of a specific machine or process control system.

As the picture shows, basic control elements—without switches, overload protection, and cabinet—are mounted on a base plate and all connections brought out to a terminal strip. The Variac, which can be manually or automatically positioned, can mount at any convenient location. The diagrams show the model in schematic form and how the terminals can be connected for the basic functions of starting, stopping, reversing, and braking.

This line of controls in conventional form has been widely applied on lathes, machine tools, and for spindle and feed drives. The approach should especially appeal to the control engineer who is working with a product or system where a rotational speed must be adjusted in response to an electrical control voltage. General Radio Co., 275 Massachusetts Ave., Cambridge, Mass.

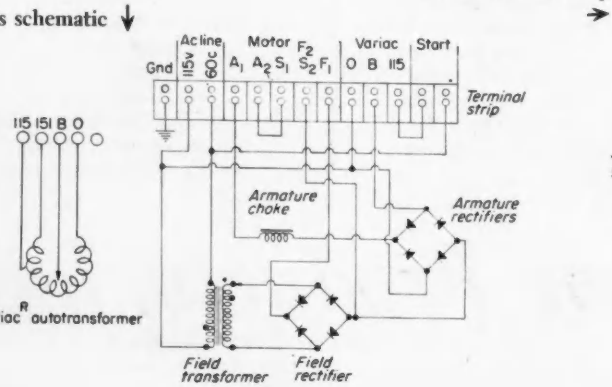
Characteristics

(for seven gradually-rated models)

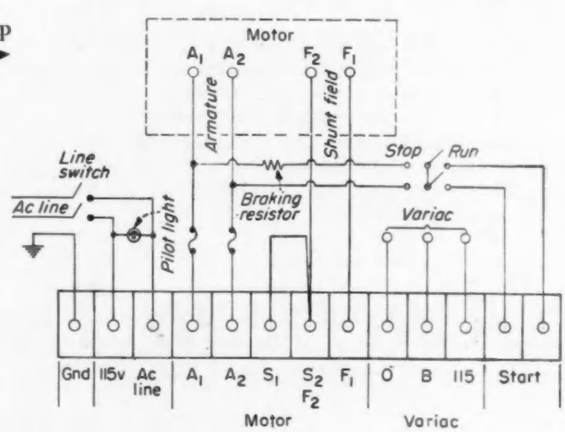
Motor hp range. .1/15 and less to 1½ hp
Power Supply. .115 and 230 v; 1.5 (single phase 60 cps) to 8.5 full load amps
Input Power. .Full Load. .175 to 1,950 w
Standby Load. .none to 90 w
Armature. . . . . .8 to 6 amp
0-115 v and 0-230 v
Field. . . . . .2 to .5 amp 38 to 128 v
Speed Range. . . .0-1.15 rated to 0-2 rated

Circle No. 1 on reply card

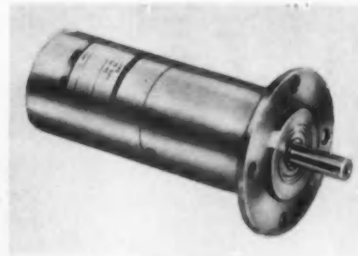
It's schematic ↓



Functional hook-up →



IT'S SMALL, BUT SUCH TORQUE ABOUT IT



Application

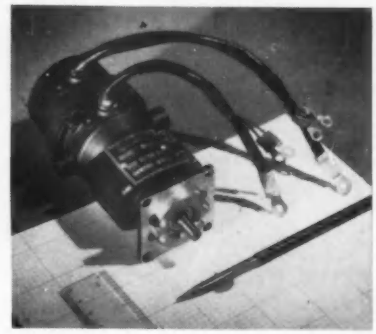
This sub-miniature planetary-gear-reduced motor meets all military specs and packs a sizeable torque in little space. It also can be furnished with governors for close speed control. *Globe Industries, Inc., 1784 Stanley Ave., Dayton, Ohio*

Characteristics

Diameter .... $\frac{7}{8}$ in.
Length ....$2\frac{1}{2}$ to $3\frac{11}{64}$ in. depending on speed-reduction rates
Weight .... as low as 5 oz.
Reduction Ratios .... 19 are available
Type .... permanent magnet dc

Circle No. 2 on reply card

STOPS BEFORE IT CAN TURN AROUND



Application

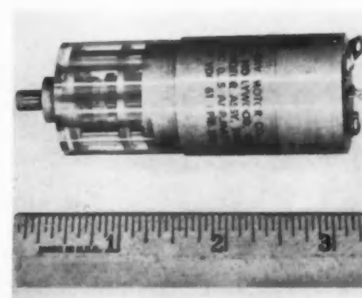
An integral brake, separately actuated from 28 vdc, can bring the armature of this permanent-magnet motor to a dead stop from full speed within one shaft revolution. It is designed for continuous-duty applications requiring high speed and call-halt regulation. *Dalmotor Co., 1381 Clay St., Santa Clara, Calif.*

Characteristics

Rated Speed .... 4,500 rpm
Starting Torque ..... 50 oz-in. at 10 amp
Total Input Current .. 2.5 amp with 40-watt load (includes .25 amp brake current)
Dynamic Torque ... 100 oz-in. minimum
Weight .... 2.4 lb
Power Requirements .... 28 vdc

Circle No. 3 on reply card

PETITE, BUT PERFORMS AND LASTS LIKE PACHYDERM



Application

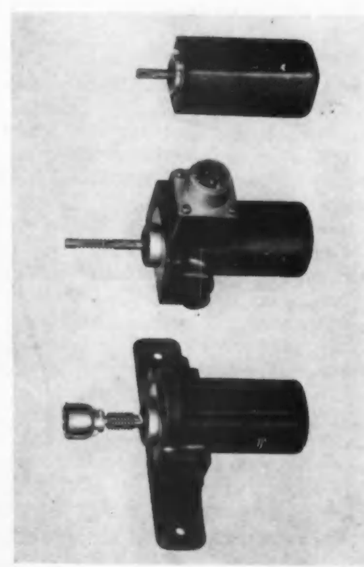
An aluminum alloy case; plastic molded brush housing; permanently sealed and greased ball bearings; a precision armature—these and other attributes give this miniature permanent-magnet dc motor precision and endurance. It has been designed especially for timing equipment and other constant-speed—continuous-use applications. It meets or exceeds all pertinent requirements of AN-M-40. *El Ray Motor Co., N. Hollywood, Cal.*

Characteristics

Input Voltage .... 6 to 30 vdc
Output .... 6 watts max. for continuous duty, 12 watts max. intermittent
Output Speed .... designed for from $\frac{1}{2}$ to 9,000 rpm according to gearing
Control Range .. within 1 per cent for constant load within 10 per cent voltage range
Size .... 2.8 in. long, $1\frac{1}{8}$ in. od
Weight .... $4\frac{1}{2}$ oz

Circle No. 4 on reply card

THIS TRIO IS SPEEDY, AMBIDEXTROUS



Application

Here are three styles of related miniature electric motors for high-speed applications. Top unit is for unirotational and reversable operation with or without integral filter. Middle unit is for same duty but can be supplied with magnetic brake. Lower unit is unirotational only, and has thermistors in its field to compensate for temperature changes' effect on speed. *Pacific Div., Bendix Aviation Corp., 11600 Sherman Way, North Hollywood, Calif.*

Characteristics

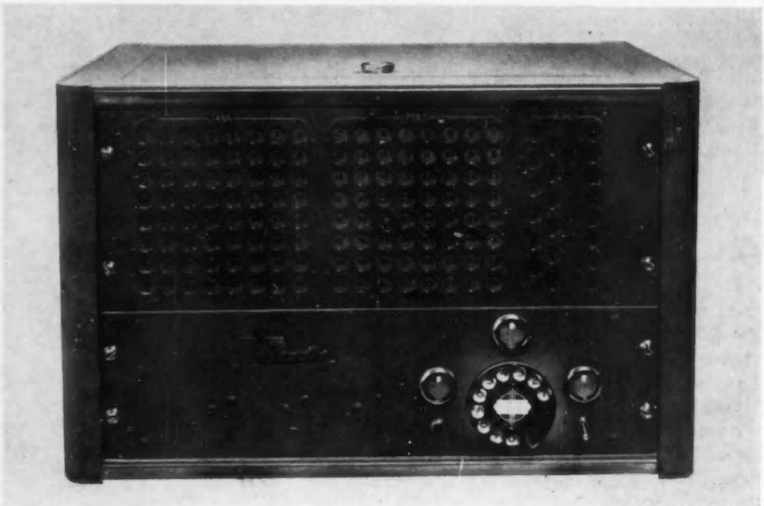
TOP UNIT:
Type ..... split series 24 vdc or 110 vac
Rated .. 2.5 oz-in. for duty up to 160 deg F
Weight .... 13 oz
Dimensions .... 3 x 3 x $2\frac{1}{2}$ in.

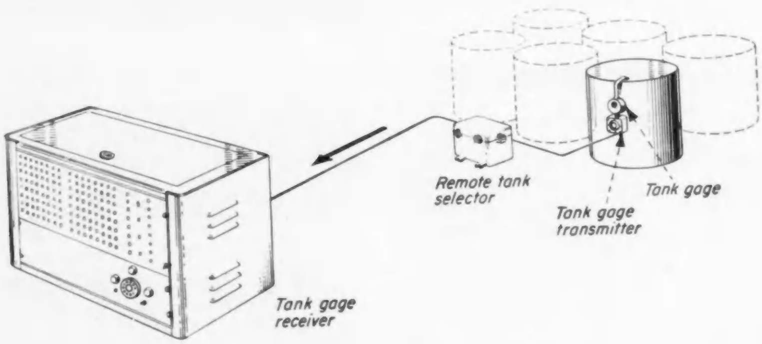
MIDDLE UNIT:
Type .... "Square" split series 24 vdc
Rated ...... 4 oz-in. for duty to 165 deg F
Size .... 1 in. sq by 2 in. long
Meets AN-M-40 and MIL-E-5272

BOTTOM UNIT:
Type .... shut field type 24 vdc
Rated .. 1 oz-in. for duty up to 160 deg F
Weight .... 13 oz

Circle No. 5 on reply card

DIGITS IN CONTROL





DIGITAL "DIRECTOR" tabs, controls remote affairs, using either tone or pulse telemetered signals.

Digital supervisory control at great distance is a sought-after function in great bulk materials-moving systems. But two things have retarded ready adoption of digital telemetering techniques: the cost of specialized systems and the difficulty of securing transmission channels.

Here is a new system with thoughtful answers to these problems. It is a "packaged" digital supervisory control that can be set up to handle either frequency-coded or pulse-coded signals. It thus can avail itself of any electrical transmission medium, including telegraph circuits, telephone lines, UHF radio, or microwave links. Voice communication can be time shared where voice-channel bandwidth exists.

The system offers economy through its building-block concept. Basic plug-in units and printed circuitry are employed. Functional systems can be thrown together for a specific job.

A wide use for the pulse-coded system is remote tank gaging—as indicated in the sketch. This system allows selection of a given tank, tank self-identification, and transmission of level information in $\frac{1}{8}$ in. increments to 60 ft. This information is coded in digital form and can be moved over a simple two-wire telegraph circuit. The pulse system features minimum bandwidth requirements and electro-mechanical and non-electronic equipment.

The frequency-coded system features very rapid data transmission and thus applies to remote control of pump station operation, electrical substations, and similar installations. Briefly, the remote measuring device drives a coder, which passes block tones from stable oscillators to the transmission line. At the supervisory station these tones are detected, amplified, and routed to a decoding relay bank. This positions the output register in agreement with the measured value. *Pacific Div., Bendix Aviation Corp., 11600 Sherman Way, North Hollywood, Calif.*

Some Characteristics

Frequency Code System:
- Transmission Rate.....200 bits per sec
- Tone Oscillator Freq...500 through 3,100 cps in 200 cycle increments
- Required Bandwidths......2,600 cps

Pulse Code System:
- Transmission Rate......10 bits per sec
- Required Bandwidth...........30 cps

Common to Both Systems:
- Measurement Digitizers....
  - liquid level
  - pressure
  - temperature
  - flow
  - shaft position
  - voltage, current, power
- Control Digitizers....shaft positioners
  - on-off controllers
- Display & Recording Forms..
  - visual (lamp bank)
  - electric typewriter
  - card-punch

Circle No. 6 on reply card

Decoding relay bank

FLIP-FLOPS fast and forcibly.

The output of this high-speed flip-flop will operate a similar unit. For use in frequency division and counting, this plug-in unit can be taken apart and assembled without tools. *EECO Production Co., Los Angeles 5, Calif.*

Characteristics

Input range	0 to 1 mc
Input voltage	80 v at 500 KC
Output voltage	80 v

Circle No. 7 on reply card

PULSE STRETCHER takes five.

Turning short pulses to long ones is the business of this Expoxy cast 'Pulse Expanding Network.' Output amplitude may be varied proportionally with input amplitude or pulse duration, or kept constant with varying of input amplitude or pulse width. *The Gudeman Co. of California, Inc., 9200 Exposition Blvd., Los Angeles 34.*

Characteristics

Input	.05 to 2 microsec pulse
Output	5 microsec pulse
Temperature range	—70 to 135 deg C
Size	2 x 1¼ x ⅜ in.
Weight	45 grams

Circle No. 8 on reply card

NUMBERS MACHINE plugs in neatly.

A compact decade counter utilizing the EIT decade scaler tube has been announced by Ransom Research. It uses only one miniature tube in addition to the decade scaler tube. The 40 kc and 100 kc types can be furnished with an input shaper circuit, requiring an additional tube. The 10 cps unit has an output stage to drive a mechanical counter. *Ransom Research, PO Box 382, San Pedro, Calif.*

Characteristics

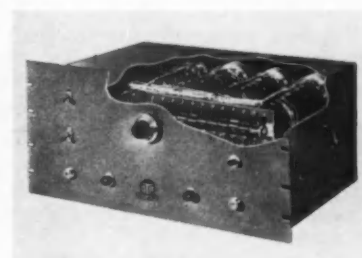
Size, all types	1¾ x 3¾ x 3¼ in. without tubes
Weight	11 oz with tubes
Scales	20 kc, 40 kc, 100 kc, and 10 cps

Circle No. 9 on reply card

DIGITAL DISPLAY from diminutive dial.

Borg's Microdial is being heralded by its maker as something phenomenal —and perhaps with no exaggeration. Each turn of the 1⅝ in. diam knob is read in hundredths directly on its face, with a ten revolution at 100 rpm input maximum. Microdial can be set to an accuracy of 1 part in 1000. It includes a brake lever. *George W. Borg Corp., Janesville, Wis.*

Circle No. 10 on reply card



10,000 CONTACTS convert analog to digital.

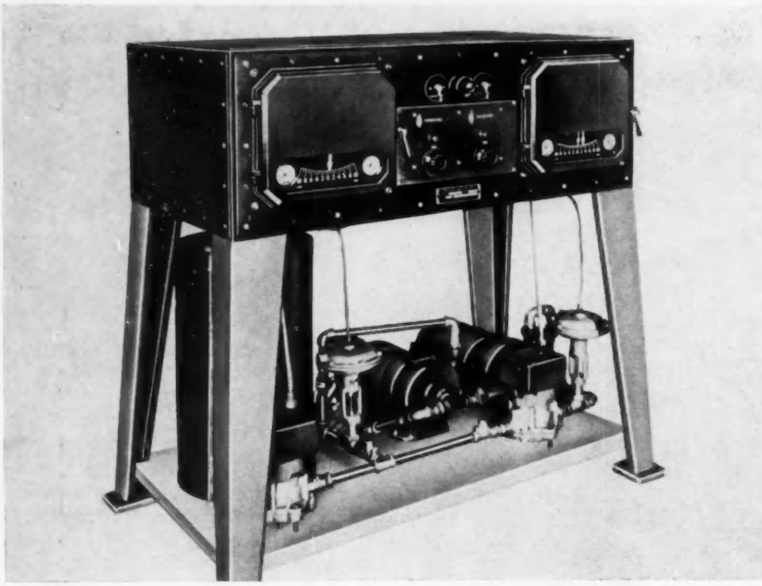
An analog-to-digital converter based on the null-voltage principle, the Quantasweep operates with an accuracy of one part in 10,000. Used with a potentiometer requiring an input of only .007 in.-oz, the Quantasweep can provide digital information on shaft positions or quantities measurable as a voltage. *EE Division of Oerlikon Tool & Arms Corp. of America, Asheville, N. C.*

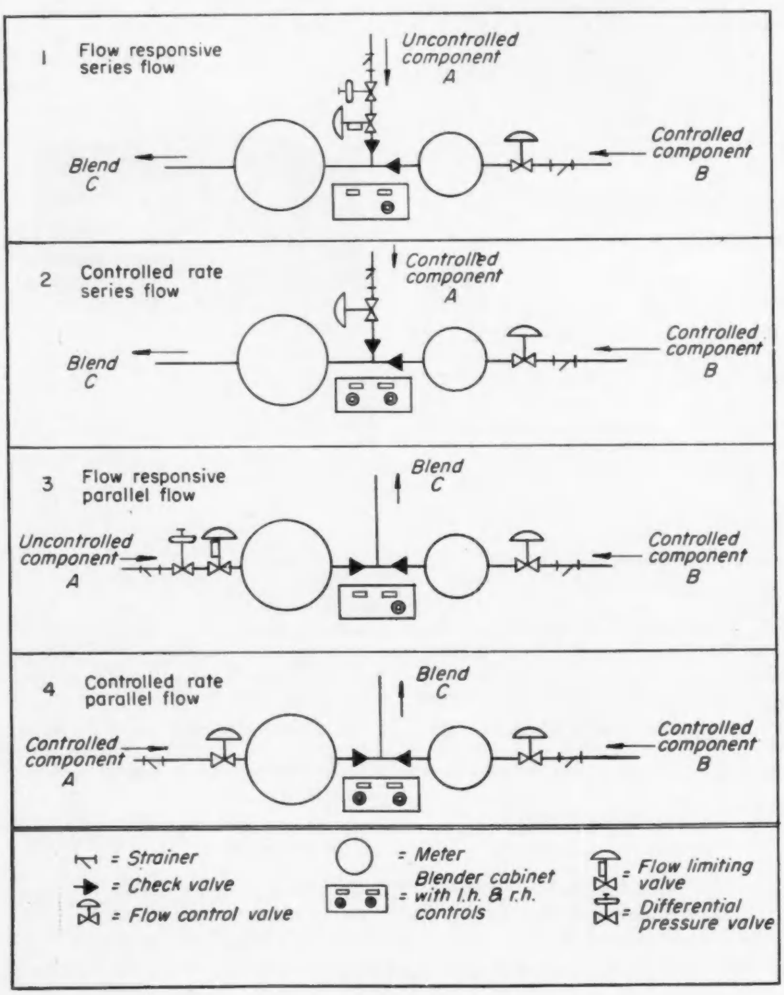
Circle No. 11 on reply card

FEEDBACK FACT

Posed: A "seeing aid" for blind pedestrians.

Solved: Franklin Institute has come up with a compact oscillator-equipped cane that squeals an alarm when the cane tip moves within 4 in. of a solid object. Powered by small batteries, the cane will cost about $50.





BLENDING "PACKAGE" should obsolete liquid-batching systems.

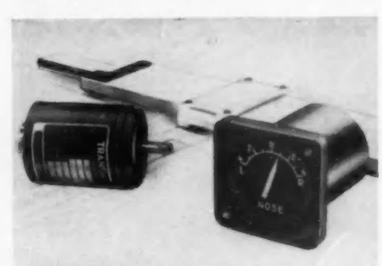
As author Lawrence Lowey spelled out, in the September issue of CONTROL ENGINEERING, the technique of automatic liquid proportioning has advanced to such an art that batch blending of liquids in industry should be as extinct as the Dodo. But this is just not the case. Too many plant people still either fail to see how a simple flow-control system could supplant their tanks, valves, and scales or shudder at the revamping necessary to such a metamorphosis.

But here, perhaps, is the answer. Here is a two-component "packaged" automatic liquid-blending system designed to be shoved up to the two supply lines and go right to work. It contains all the necessary instruments, flow pickups, control valves, and even strainers, traps, and filters. And it is capable of various blending arrangements—as indicated by the four hookup sketches.

We can visualize countless applications for this practical system: caustic blending; beer standardization; cutting of fuel oil. The maker's detailed 8-page catalog has more suggestions and information than we can print here. *Proportioners, Inc., Div. of B-I-F Industries, Inc., Providence, R. I.*

Circle No. 12 on reply card

SERVOS



"WHERE" METER locates plane parts.

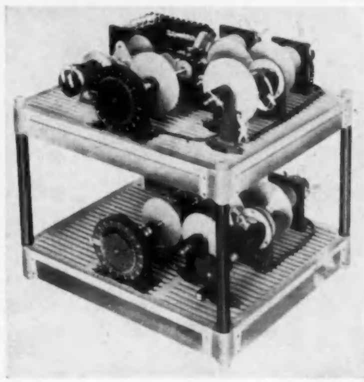
This indicates positions of trim tabs, nose wheels, etc. A three-wire dc synchro drive, and a miniature, light,

hermetically-sealed package requiring only 1.75 in. of panel space at the receiver end indicates that this position indicator was intended for aircraft use. A magnetic "pull-off" holds the pointer off scale to warn the pilot of electrical power failure. No field adjustments are needed. *Avien, 58-15 Northern Blvd., Woodside 77, N. Y.*

Characteristics

Operating Voltage	28 vdc
Power requirements	2 watts
Accuracy indicator	±50
Transmitter	±20
Weight indicator	2 lb
Transmitter	2 lb
Temperature operating range	−65 to 165 deg F
Altitude maximum	60,000 ft

SERVO "ERECTOR-SET" has more, better components. Production precision parts aim at more realistic mockups.



Characteristics

Grid	Aluminum. Flat to .002 in.
Alignment coupling backlash	.0015 at 1 in. radius
Shaft tolerances	+.0000 −.0002
All bore tolerances	+.0002 −.0000
No. of different gears available	10,260
Gear tolerances	AGMA precision class #2 (Total indicator runout not over .0005 in.)
Torque range of adjustable anti-backlash split gears	0-30 oz-in. through 45 deg
Slip-clutch-built-in-gear range	0 to 60 oz-in.
D. Pitches available	32, 48, 64, and 96 in 14½ and 23 deg pressure angles

The idea of producing standardized construction components has advanced quite a way from the day the first nuts and bolts could be bought over a counter. This latest addition to the breadboard maker's art adds new items and new dependability to the field. Starting with a new grid-plate design aimed at greater dimensional stability, the Belock people have made as many parts as possible agree with government specifications to reduce to a minimum the variations between the mockup and production model. In addition to hangers, servo motors, synchros, pots, gears, dial assemblies, differentials, component shaft adapters, electrical and mechanical stops, shafts, collars, etc., is a new line of miniature magnetic clutches with response time in the 5-millisec range, a new mechanical integrator, a new remote positive-position mechanism, and a new subminiature differential. Edge-to-edge grid arrangements are possible to increase working surface area. The parts shown in the photograph can be purchased for roughly $\frac{1}{10}$ their cost if specially designed and built in a typical model shop, the manufacturer claims. *Instrument Components, Inc., College Point, N. Y.*

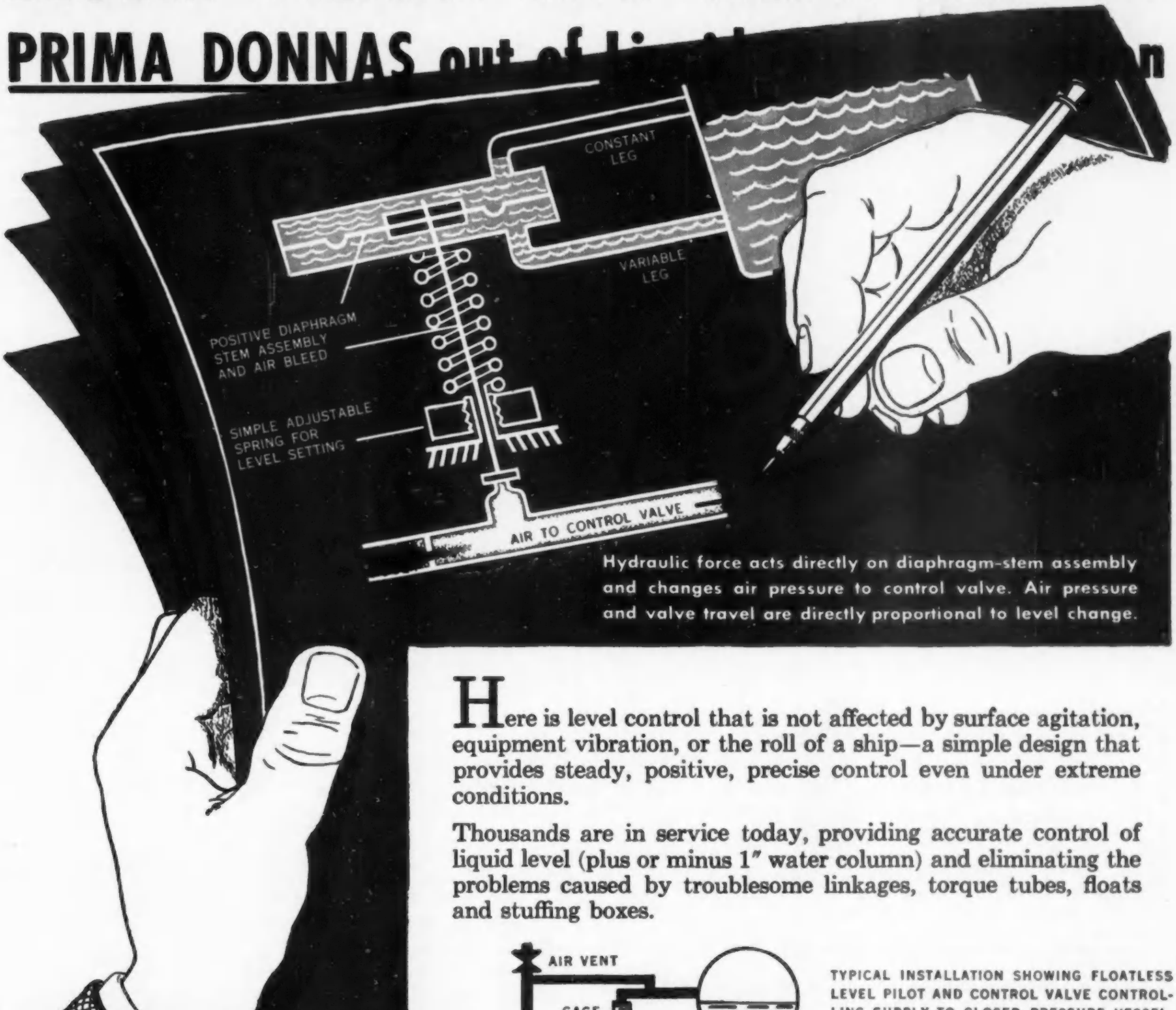
Circle No. 13 on reply card

FEEDBACK FANCY

Needed: A way to conserve and effectively use water in lawn sprinkling.

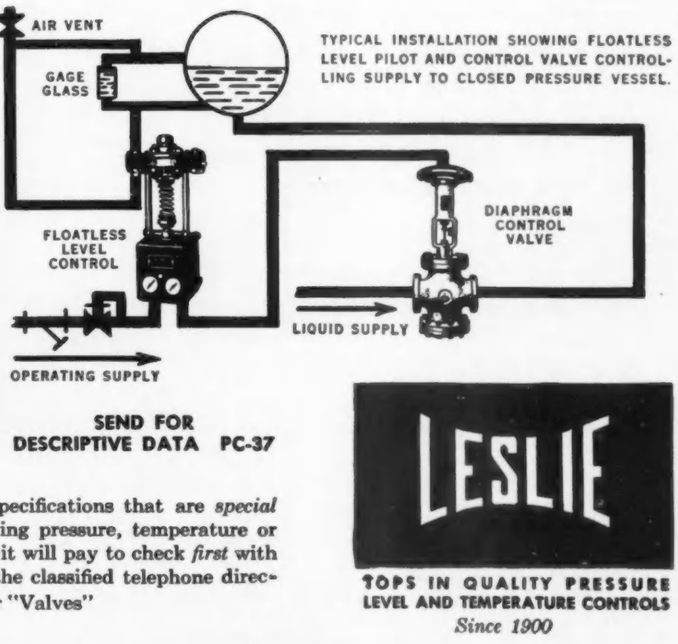
Suggested: A calibrated permanently-mounted soil probe which would start and stop sprinkling systems in accordance with optimum moisture conditions for the area.

LESLIE *Floatless* Level Control takes the PRIMA DONNAS



Here is level control that is not affected by surface agitation, equipment vibration, or the roll of a ship—a simple design that provides steady, positive, precise control even under extreme conditions.

Thousands are in service today, providing accurate control of liquid level (plus or minus 1″ water column) and eliminating the problems caused by troublesome linkages, torque tubes, floats and stuffing boxes.



Note these special features—

1. **Can be installed anywhere below liquid level . . . on control panel, if desired.**
2. **Simple, compact, one adjustment unit . . . weighs only 40 lbs.**
3. **Diaphragm stem assembly is only moving part. Diaphragm element doesn't require recalibration during service.**

SEND FOR DESCRIPTIVE DATA PC-37

When specifying . . .

Here's *another* LESLIE *standard* item to fit specifications that are *special* orders with most manufacturers. When specifying pressure, temperature or level controls—for new or replacement service—it will pay to check *first* with your nearest LESLIE engineer. He's listed in the classified telephone directory in principal cities . . . under "Regulators" or "Valves"

LESLIE

TOPS IN QUALITY PRESSURE LEVEL AND TEMPERATURE CONTROLS
Since 1900

LESLIE CO., 211 Grant Avenue, Lyndhurst, New Jersey

NEW PRODUCTS

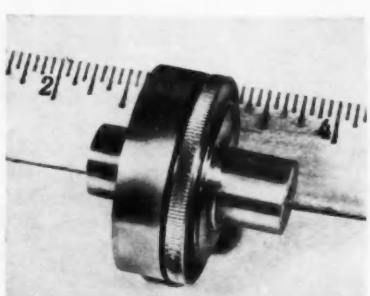
SERVO AMPLIFIER is versatile, compact.

A modulator-amplifier called Spelco-Serv will accept ac, dc, and phase-shift signals, sensing their phase or direction. Loads may be resistive or inductive. The Spelco-Serv can also act as a relay since no power is supplied the load during standby. An ac or dc (or both) input can be used to produce either an ac or dc output. *Standards Plastics & Electronics Co., Los Angeles, Calif.*

Characteristics

Gain	300 to 1000
Input	50 millivots min.
Output	100 watts
Size	12 cubic in.
Weight	1 lb
Power Supply	60, 200, 800 cps

Circle No. 14 on reply card



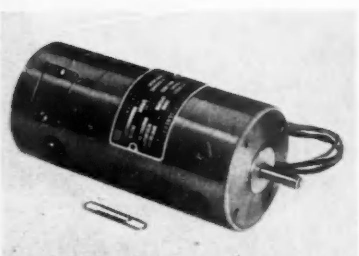
SLIP CLUTCH will take only so much.

This new line of miniature slip clutches uses silicone putty in one series and a cantilever spring deflection principle in another series to provide a stable slip torque at a variety of rpm and over long periods of continuous slippage. Extremely small size aims it for the office and business machine, computing, and recording fields. Its dependability is claimed to be heretofore unheard of. *Radial Metal Products, Inc., 131 Prince St., New York 12, N. Y.*

Characteristics

Size	1⅛ in. diam by ⅜ in. thick to 2¼ in. diam by ½ in. thick
Slip torque range	1/50 oz-in. to 20 lb-in.
Temperature range	−30 to 250 deg F
Error	3 percent for constant temperature
Slipping Life	Very high. Putty model is virtually unlimited

Circle No. 15 on reply card



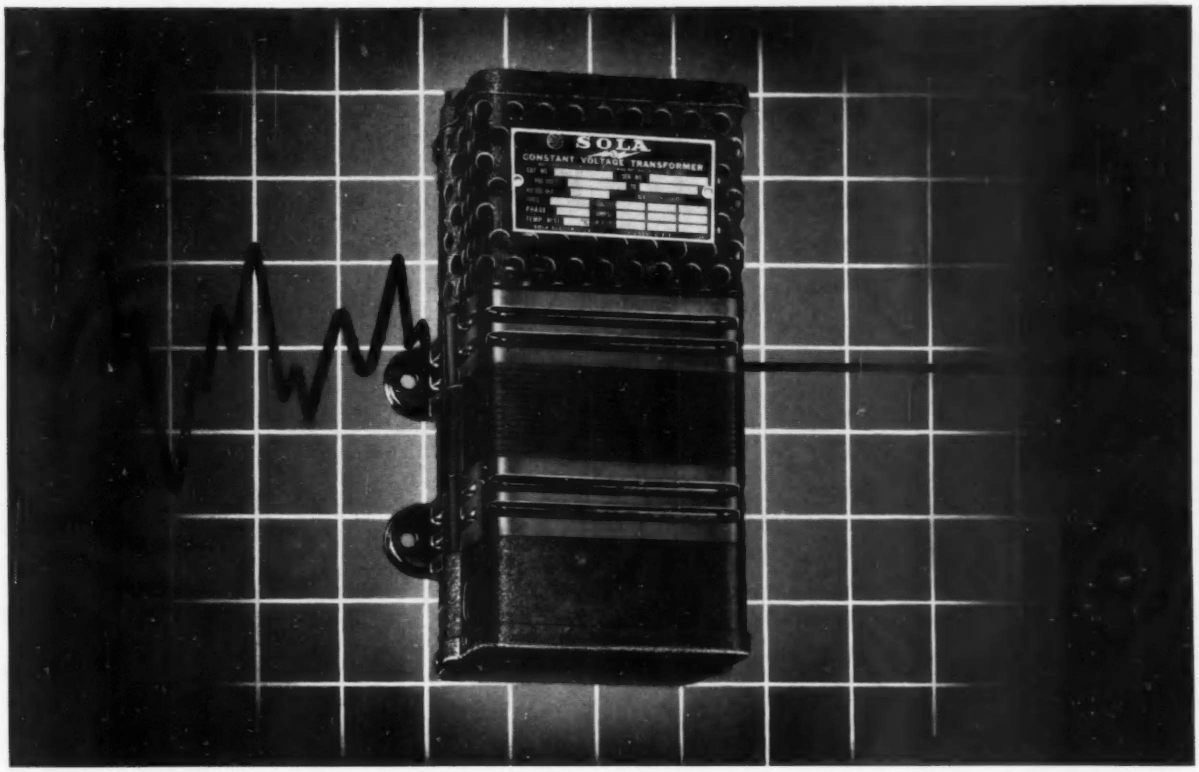
KNOWS HOW it goes and tells well.

A new line of dc motors designed to indicate electrically their speed via built-in tachometer generator is available. All have auto-reset thermal overload protection. Capacitor filters for both motor and generator are available. Both PM and wound-field types for any combination of armature and field voltages can be supplied. *Electric Indicator Co., Inc., Springdale, Conn.*

Characteristics

Speeds	to 10,000 rpm
Voltage	6 to 220
Output	5 to 100 watts
Tach output	6v per 1000 rpm
Tach error	10 per cent
Tach linearity	1 per cent

Circle No. 16 on reply card



Automatic voltage stabilization for sensitive control components

You can eliminate the variable of erratic line voltage on voltage-sensitive elements of automatic control equipment. Do it simply and economically with the Sola Constant Voltage Transformer.

The Sola stabilizer is a static-magnetic regulator which differs from regulators depending solely upon saturation of core materials; or electronic types employing tubes. Their characteristics, listed below, make them ideal for controlling input voltage to voltage-sensitive electronic and electrical control components.

1. Regulation within ±1%, with primary voltage (transient or continuous) variations as great as 30%.
2. Response time less than 1½ cycles.
3. No moving or wearing mechanical parts, nor vacuum tubes; requires no manual adjustments.
4. Completely automatic, continuous regulation.
5. Self-protecting against short-circuits on output.
6. Current-limiting characteristic protects load equipment.
7. Isolates the input and output circuits.

Forty-three Sola stock units are available in a wide variety of ratings, voltages and types. In addition, custom-designed units can be manufactured (in production quantities) to meet specific requirements.

The experience of the world's largest manufacturer of constant voltage transformers is available to you. We invite you to discuss your voltage stabilizing problems with a Sola Sales Engineer.

SOLA *Constant Voltage* **TRANSFORMERS**

WRITE FOR LITERATURE. Sola Constant Voltage Transformers are completely described in a 24 page manual. Write for a copy of 26A-CV-200 on your letterhead, please.

CONSTANT VOLTAGE TRANSFORMERS for Regulation of Electronic and Electrical Equipment • LIGHTING TRANSFORMERS for All Types of Fluorescent and Mercury Vapor Lamps. • SOLA ELECTRIC CO., 4633 West 16th Street, Chicago 50, Illinois, Bishop 2-1414 • *BOSTON:* 272 Centre Street, Newton 58, Massachusetts • *NEW YORK 35:* 103 East 125th Street • *LOS ANGELES 26:* 2025 Sunset Boulevard • *PHILADELPHIA:* Commercial Trust Building • *CLEVELAND 15:* 1836 Euclid Avenue • *KANSAS CITY 2, MISSOURI:* 406 West 34th Street • *Representatives in Other Principal Cities*

NEW PRODUCTS

TIMERS & RELAYS

CYCLE TIMER works over wide range.

Zenith's new timer has three interesting features: the availability of an extremely wide range of time cycles; a dial which indicates the percentage of the time cycle on; and a visual indicator which tells at a glance whether it is in the on or off condition. *Zenith Electric Co., Dept. CLM, Walton St., Chicago 10, Ill.*

Characteristics

Size	5 x 3 x 3 in.
Time Cycles Available	15 sec to 24 hr
On or Off Periods Available	Up to 94 per cent of cycle

Circle No. 17 on reply card

DIALS AWAY the time with ease and accuracy.

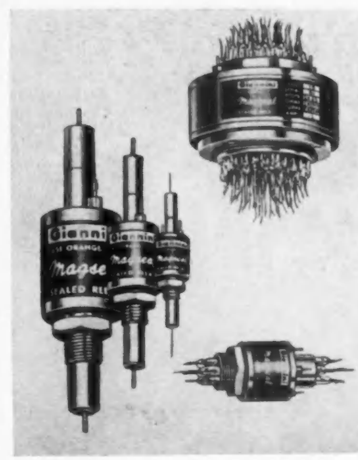
An adjustable time delay relay has been released to the non-military market by the A. W. Haydon Co. Using

an escapement similar to those in alarm clocks to operate its governor, the adjustable delay can be set with high accuracy over its entire range. *A. W. Haydon Co., Waterbury, Conn.*

Characteristics

Accuracy	±1 sec or ±1 per cent
Timing motor voltage	24 to 29 vdc
Life	500 hr
Contact rating	1 amp inductive
Delay range	2 to 30 sec

Circle No. 18 on reply card



ETERNITY, INSTANTANEITY describe life and speed of relay.

Giannini claims a new principle in relay construction: the contacting elements are sealed in a glass envelope with the coil on the outside. The nobel-metal-faced contacts are closely spaced cylinders, which move together when in proximity to a magnetic field. A variety of windings are available for different sizes of contacts. Permanent-magnet models can be used for biased operation, and two-coil models for differential behavior. *G. M. Giannini & Co., Inc., Pasadena 1, Calif.*

Characteristics

Life	1 billion cycles
Response rate	60 cps max
Actuation speed	1 or 2 ms
No. of contracts	up to 109

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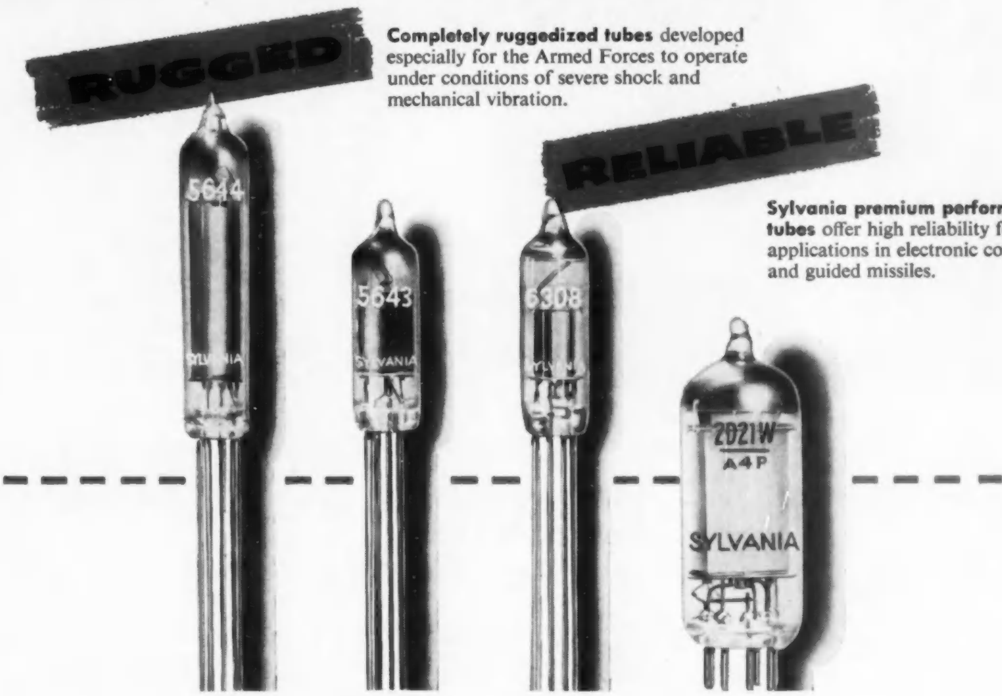
NOW! For your most important electronic control applications

Completely ruggedized tubes developed especially for the Armed Forces to operate under conditions of severe shock and mechanical vibration.



Sylvania premium performance tubes offer high reliability for applications in electronic computors and guided missiles.

SYLVANIA GAS TUBES

To MEET your electronic control equipment needs, whether military or commercial, Sylvania offers a wide selection of gas tubes engineered to meet the most rigid specifications. These include tubes for commercial use in applications where reliable performance is required under difficult conditions of shock and vibration. Some Sylvania gas tubes have been especially designed to meet MIL-E-1 specifications.

Whatever your needs, you can select any Sylvania gas tube with confidence that it is manufactured under the same standards of quality and dependability which recommend their use in vital military equipment.

Sylvania's complete line offers you dependable tube types for your most important control functions.

A SYLVANIA TYPE FOR EVERY NEED

Type	Application
0A2	voltage regulator
0A4G	relay and grid controlled rectifier
0B2	voltage regulator
0B3	voltage regulator
0C3	voltage regulator
0D3	voltage regulator
1B59/R1130B	glow modulator diode
1D21/SN4	strobotron
2D21	relay and grid controlled rectifier
2D21W	relay and grid controlled rectifier
R4330	strobotron
S413	strobotron
SA309	strobotron
1237	full-wave rectifier
20A5	trigger tube
5643	relay tube
5644	voltage regulator
5651	voltage reference
5823	relay, rectifier
6D4	relay, relaxation osc. noise generator
6308	voltage reference
6483	trigger tube

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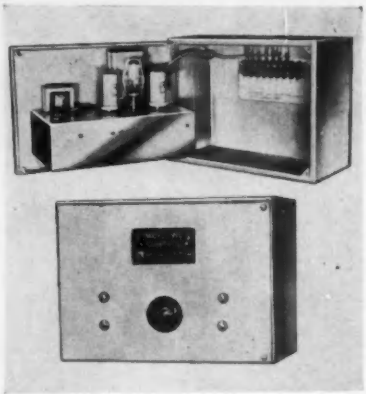
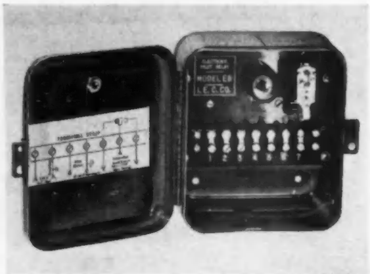
NEW PRODUCTS



ELECTRONIC RELAY adjusts easily for load.

For heavy industrial uses, such as rolling mills, this electronic load relay meets the need for a reliable device to actuate water sprays, coils, boilers, etc. in synchronization with passage of strip, plate, and rod. It does not load circuits and operates on minimum signal changes. It will not burn out with overload and is easily adjusted by an external knob. Mounted in a heavy steel gage enclosure, it is suitable for panel or wall locations. *Industrial Gauges Corp., Englewood, New Jersey*

Circle No. 20 on reply card



PILOT RELAY'S gain is 106 amps.

One feature of this electronic pilot relay is a light which indicates "on" or "off" condition with the case closed. No warm-up time is required. *Industrial Electronic Controls Co., Brooklyn 29, N. Y.*

Characteristics

Contacts .... SPDT
Size .... 4 x 6 x 7 in.
Actuating current .... 2 microamp
Contact rating .... 5 amp at 115 vac

Circle No. 21 on reply card

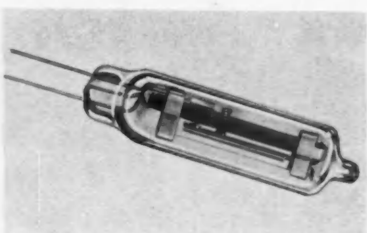
RELAY'S RECTIFIER is built-in germanium diodes.

A hermetically sealed chatter-free ac-dc relay has been announced by Hi-G. It will operate on dc of either polarity. A balanced rotating armature is used to withstand high shock accelerations. Relay interconnections and circuit components can be mounted internally. *Hi-G Inc., Bradley Field, Windsor Locks, Conn.*

Characteristics

Max shock accelerations	100 G
Life	100,000 cycles at 4 amp
Contacts	Up to 6

Circle No. **22** on reply card



"HOT-WIRE" SWITCH is a current limiter.

Operating in a small hermetically-sealed package, this SPST normally-closed hot-wire switch is designed to limit current flow to its nominal value. Its purpose is the protection of sensitive radio circuits from overload without completely interrupting operation, as would a fuse. When the current level exceeds the critical point the contacts make and break rapidly causing the current flow to average

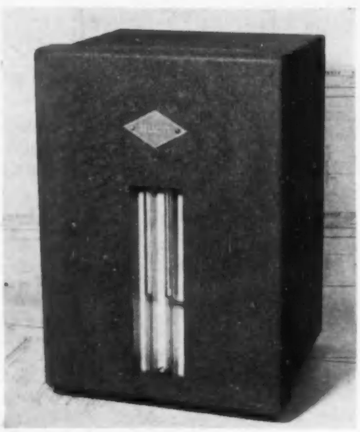
out to the desired preset value. *Thomas A. Edison, Inc., Instrument Division, West Orange, New Jersey*

Characteristics

Dimensions..... $\frac{9}{16}$ in. diam x $2\frac{1}{8}$ in. long
Temperature Compensation....0 deg to 90 deg ambient range
Critical Current........125 milliamperes ±25 ma
Shock resistance..................60g

Circle No. 23 on reply card

COMPONENTS FOR PROCESSING



MANOMETER blows bubbles to hold two levels.

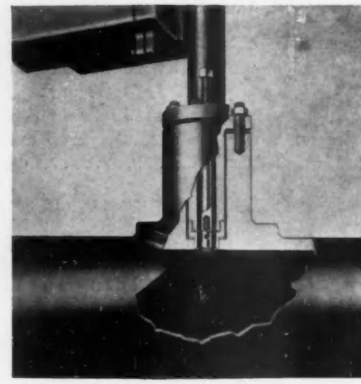
This deceptively simple-looking twin-column manometer has two hidden features inside its case. First it contains a compact metering-type air compressor. Also built in is an electronic relay, which picks up column-height differences.

This is a differential level-control manometer. The air is supplied from the meter to remote vessels and bubbled against hydraulic head. The bubble tubes are connected also to opposite arms of the manometer. This gives a continuous indication—in the two columns—of static pressure or liquid-level differential. At a preset limit, the unit will send a control signal to take care of the untold conditions in the remote vessels.

The instrument measures 11 x 17 x 11 in. and weighs 60 lb. It is designed for either wall or flush mounting. *Thermo Instruments Co., 1310 Old County Road, Belmont, Calif.*

Circle No. 24 on reply card

NEW PRODUCTS



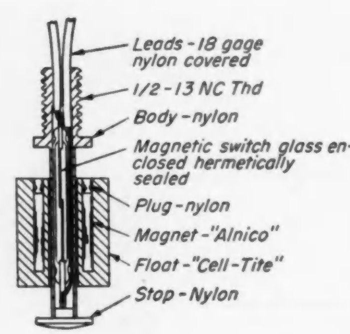
PRESSURE PICK-UP halts no flow.

A process pressure transmitter that mounts flush with the inside of the pipe has all parts in contact with fluids of stainless. Diaphragm motion is linked to the core of a differential transformer, resulting in linear voltage output. As the P3T requires no stagnant pressure lines, the need for heat-jacketing is eliminated in high temperature systems. *The Swartout Co., Cleveland 12, Ohio.*

Characteristics

Range	0-200 to 2500 psig
Temp max	300 deg C and higher on order
Sensitivity	.005 per cent
Error	.1 per cent

Circle No. 25 on reply card



FLEA-WEIGHT is whale of a switch.

A new Revere switch, known as the F-8685 Level Indicator Switch, has been designed for commercial fluid level control applications that require light-weight, compact, trouble-free operation with hard-to-handle fluids. The synthetic rubber float has no

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(49) MAGNETIC TAPEDRUM. Clevite-Brush Development Co., Bulletin 4310-1a-54, 6 pp. Describes an inside-out magnetic drum in which magnetic heads are in a rotating drum while storage area is a wide endless belt of magnetic material. Belt is stationary except when new area is to be scanned. Discusses advantages and applications.

(50) INTEGRAL-HP SERVO MOTORS. Reliance Electric and Engineering Co., Bulletin C-2002, 12 pp. Describes a line of dc motors from 7½ to 250 hp specifically designed from improved dynamic response. Discusses typical applications and mechanical and electrical characteristics that lead to lower time constants and high strength.

(51) DIGITAL PLOTTER. Tally Register Corp., Brochure, 4 pp. Gives complete specifications for device that will plot continuous two-coordinate curves from digital data. Input can be from digital computers, card readers, keyboards or tapes.

(52) PRECISION POTENTIOMETERS. Bourns Laboratories, General catalog, 60 pp. In formation on complete line of linear-motion potentiometers and potentiometer instruments. Instruments include pressure senstive and acceleration sensitive devices. Useful electrical and mechanical specifications are presented.

(53) LONG-STROKE DIAPHRAGMS. Bellofram Corp., Brochure BF 100, 14 pp. Selection and application details on a line of long-stroke, deep-convolution, constant-area diaphragms. They can be used in instruments, power actuators and motors and as seals.

(54) INDUSTRIAL ELECTRON TUBES. Radio Corp. of America, Bulletin 3F215, 12 pp. Describes a line of reliable industrial tubes. Points out service and reliability features.

(55) VISCOMETERS. Drage Products, Brochure, 12 pp. Illustrates the application of a Swiss made viscometer to both laboratory and in-plant process and quality control. Has section devoted to rheological characteristics of products.

(56) TIMERS AND COUNTERS. Eagle Signal Corp., Bulletin 340, 4 pp. Covers a variety of relay-type timers and counters.

(57) CHECKING BRIDGE-TYPE TRANSDUCERS. Statham Laboratories, Inc., Instrument Notes 28, 8 pp. Technical discussion covering a new system for monitoring the over-all transduction ratio for analog recording channels employing bridge type transducers.

(58) NUCLEAR INSTRUMENTS. The Ohmart Corp., Bulletin 105, 8 pp. Describes a series of industrial instruments that use atomic cells for the direct conversion of radioactive energy into electrical energy. Instruments include a specific gravity meter, a level gage, and associated equipment. Equipment specifications and application data are covered.

(59) INDUSTRIAL CONTROLLERS. Leeds and Northrup Co., Folder ND47 (7), 13 pp. Detailed performance and design specifications for new series of electronic controllers. Available for proportional action control, and position-adjusting type or duration-adjusting type control.

(60) ELECTRONIC TIMER. Ferra Inc., Brochure T-2, 4 pp. Discusses electronic timer that can be used for interval timing, timed delay, repeat cycling, programming and pulsing. Electrical specifications and typical circuit arrangements are included.

(61) THERMOCOUPLE ELEMENTS. Claud S. Gordon Co., Bulletin 14-15-54. Illustrates and describes a line of thermocouple elements and bare thermocouple wire. Includes application data for the various types of elements and the different metals.

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(62) PULSE-TESTING SYSTEMS. Burroughs Corp., Electronic Instrument Div., Brochure, 6 pp. Describes three pulse generators that cover a frequency range from 15 cycles to 4.5 megacycles. Basic pulse techniques plus combining details are covered.
(63) PRECISION PRODUCTION SERVICES. Daco Machine and Tool Co., Brochure 6, 20 pp. Illustrates and describes facilities for designing and producing high-precision instruments.
(64) GRAVIMETRIC PROPORTIONING SYSTEMS. Proportioneers, Inc., Div. of B-I-F Industries, Inc., File RP-2000, 8 pp. Technical presentation covering continuous gravimetric proportioning systems. Includes descriptive and application and selection data.
(65) PRESET COUNTERS. The Counter & Control Corp., Bulletin 202, 34 pp. Covers a line of predetermined counting devices for such applications as counting shaft rotations, reciprocating motions, electrical impulses, and photo cell pulses.
(66) PLANE GRATING SPECTROGRAPH. Jarrell-Ash Co., Catalog EB-10-54, 8 pp. Detailed description of versatile spectograph with order sorter. The sorter gives wide wavelength coverage and good speed at high dispersion and resolution.
(67) OSCILLOGRAPHIC RECORDING SYSTEMS. Sanborn Co., Brochure 60M-1-10b. 6 pp. Data on a cabinet type oscillographic recording system featuring interchangeable plug-in preamplifiers. Six basic types of preamplifiers are available.
(68) RECORDING CONTROLLER. Thermo Electric Co., Bulletin 62, 2 pp. Describes potentiometer pyrometer and resistance thermometer controllers with either two-position or pulse-proportional control action. Gives complete performance and electrical and mechanical specifications.
(69) PROGRAM TIMER. General Control Co., Catalog SY, 4 pp. Covers a series of synchronous motor operated timers for the automatic control of timed operations. Unit is available in four mounting styles. Cost, circuit arrangements and outline dimensions are given.
(70) DIGITAL INVENTORY EQUIPMENT. Telecomputing Corp., Brochure, 4 pp. Discusses a point-of-sale recorder and a tape-to-card converter for use in retail sales and inventory control systems. Recorder includes a marked tag puncher, an automatic typewriter and a tape punch.
(71) ROTARY MULTI-POLE SWITCHES. Electro Switch Corp., Catalog 8054-IN, 12 pp. Contains complete wiring diagrams and contact charts for voltmeter, ammeter, and voltmeter-ammeter switches. Also includes handle and panel mounting data, dimensions, special switch data and electrical ratings. Excellent illustrations.
(72) DATA-PROCESSING INSTRUMENTS. Consolidated Engineering Corp., Bulletin CEC-1301, 10 pp. Information on a complete line of data processing equipment ranging from miniature transducers to entire instrumentation systems. Photographs, technical specifications and descriptive functional diagrams are useful.
(73) ROTATING EDDY-CURRENT EQUIPMENT. Eaton Manufacturing Co., Bulletin GB2, 16 pp. Comprehensive technical treatment of the basic principles of eddy-current machinery, torque, heat and operating characteristics, cooling efficiency and control. Also includes performance and specifications for couplings, brakes, dynamometers, adjustable speed drives and special units.
(74) PNEUMATIC CONTROLLERS. Minneapolis-Honeywell Regulator Co., Bulletin ss 163-1, 2 pp. Up-to-date specifications on a line of electronic circular chart pneumatic controllers including a list of the control forms available.
(75) PRESSURE TRANSDUCER. E. V. Navbor Laboratories. Bulletin P-1, 4 pp. Describes operation, construction and specifications of a bellows type gage or absolute pressure transducer. Bellows actuates a synchro transformer. Available in ranges to 1000 psi.
(76) VOLTAGE STABILIZERS. Raytheon Manufacturing Co., Catalog 4-260, 16 pp. Information on a line of stabilizers that will meet requirements from 5 to 2,000 watts. Describes reasons for and applications of voltage stabilizers.
(77) SELENIUM RECTIFIERS AND DIODES. International Resistance Co., Bulletin SR-1A, 8 pp. Includes data on construction, applications, types, ratings, reference curves, specifications, and dc characteristics for a variety of rectifiers and diodes.
(78) FLUID SEALING DEVICES. Franklin C. Wolfe Co., Inc., Catalog, 19 pp. Describes a line of permanent seals to prevent leakage of air, gases and liquids. Includes seals for bolts, rivets and filleting; flanged fittings, hatch covers and access doors, and a line of O-rings.
(79) REGULATED DC POWER SUPPLIES. Vickers Electric Div., Vickers Inc., Bulletin 8000, 4 pp. Information on magnetic amplifier and selenium rectifier dc power supplies available in sizes from 5 to 50 kw. Contains mechanical and electrical specifications.
(80) MOTOR-CONTROL EQUIPMENT. Continental Electric Equipment Co., Bulletin 401, 8 pp. Describes modular structures used to concentrate many motor controls in a packaged unit. Layout and short circuit application data, dimensions, ratings, and specifications included.
(81) TUBE FITTINGS. The Parker Appliance Co., Data sheets 4310A14 and 4320A11, 4 pp. Describes new long-union tube fittings available in both the flared and flareless types. For interchangeability, union is same length as cross and tee.

mechanical linkage with any other part in the unit. Level control of oils, acids, and other chemicals is made possible by the nylon body and nylon jacketed lead wire. *Revere Corp. of America, Wallingford, Conn.*

Characteristics

Electrical Capacity......10 watt load at 115 vac .5 amp inductive load at 25 vdc
Size................Less than 3 cu in.
Weight ....1 oz

Circle No. 26 on reply card

BLOW HOT, blow cold is its motif.

Essentially a temperature-to-pressure converter is this weather-proof instrument. Called the 12A Temperature Transmitter, it is intended to deliver temperature information in process systems via proportional pneumatic pressure. Equipped with clamp and compensated for ambient temperature and pressure. *Foxboro Co., Foxboro, Mass.*

Characteristics

Range......50 to 400 deg. F. Can also be used between the range of −100 to 1,000 deg F
Pneumatic pressure range....3 to 15 psi
Error ....5 per cent

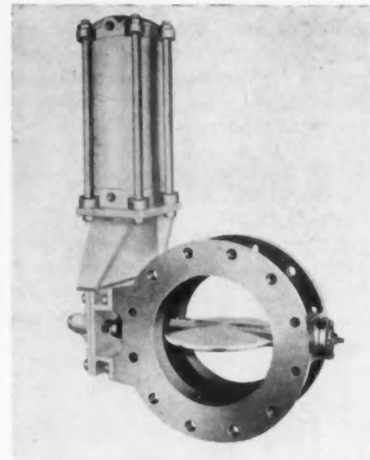
Circle No. 27 on reply card

VALVES IN CONTROL

BUTTERFLIES are now rubber seated.

Addition of rubber seating extends this line of rugged, heavy-duty butterfly valves for service requiring tight shutoff. The valves meet the American Water Works Association's Tentative

NEW PRODUCTS



Standard Specifications. No. AWWA C504-54T. Accessories include manual, electric, hydraulic, and pneumatic operators. *Builders-Providence Inc., 345 Harris Ave., Providence, R. I.*

Circle No. 28 on reply card

SELF-OPERATOR spouts out when things are hot.

This rugged, self-actuated valve performs like a king-size sprinkler system. The valve serves a water deluge or fog line in fire-liable areas. Pinpointed heat causes it to open instantly and deliver full head. It employs line pressure to close tightly without water hammer.

The valve is held normally closed by pressure of incoming water or fog on its diaphragm. However, an air pilot or solenoid, actuated by any desired number of fusible heads in danger areas, can quickly bleed this pres-

sure off to open the valve. Operation also can be controlled manually from a remote point.

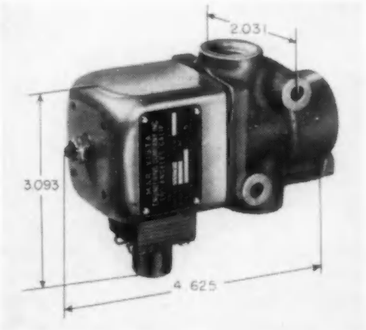
Available in various metals, the unit is rated at 250 psi. It can be installed in any position in the line. *McRae Corp., 621 South Spring Street, Los Angeles, Calif.*

Circle No. 29 on reply card

STAINLESS BODY resists corrosive flow.

A compact two-way stainless steel body fits this solenoid valve for handling corrosive gases and liquids at pressures up to 250 psi. It is available in ⅜ in. I.P.S. solenoid enclosures to meet NEMA watertight standards. Supplied for normally open operation, it will perform with long life at up to 400 cycles per minute. *Automatic Switch Co., 391 Lakeside Ave., Orange, N. J.*

Circle No. 30 on reply card



HANDLES AIR abruptly and selectively.

This solenoid operated air control valve is designed for shutoff and se-

lector service in aircraft, guided missiles and machine control. It augments the company's well known line of hydraulic units for similar service. Some characteristics: pressure range—0 to 3,000 psi; temperature range—− 65 deg F to 265 deg F; draws less than 1 amp at 24 volts dc during continuous dutp. *Mar Vista Engineering Co., 5420 W. 104th St., Los Angeles, Calif.*

Circle No. 31 on reply card

OPTICAL PYROMETER senses hot stuff sensibly.

The temperature of hot objects on the move or inaccessible material can be gaged remotely by this photoelectric pyrometer. Further, the unit can be equipped with a control relay to regulate process temperature.

The smaller element in the picture is the portable phototube and lens assembly that is sighted on the work. A variable iris in this controls the amount of radiation reaching the phototube—which allows the equipment to respond accurately even to the highest temperatures. The companion meter contains an electronic amplifier, control relay, and calibrated scale. *Photoswitch Division, Electronics Corp. America, 77 Broadway, Cambridge 42, Mass.*

Characteristics

Measuring and Control Range. . 1,000-5,000 deg. F
Sensitivity . . . . one foot candle, full scale
Power Supply. . 115 or 220 v, 50/60 cyles
Power Consumption. . . . . 12 watts
Relay. . . . . SPDT. 10 amp at 115v; 5 amp at 230v
Ambient Temp. Range. .
control—minus 32 to 125 deg F
scanner—minus 32 to 150 deg F

Circle No. 32 on reply card

Yacht Control

From "Automatic Steerers" by Theodore W. Kenyon. "Yachting," November 1954.

There is an amazing variety of yacht steering control devices available today. They obtain their directional references from such varied sources as hand-held push buttons to such complex mechanisms as servo-controlled magnetometers. Prices range from about $300 for fully automatic units.

Except for the most expensive units, the practical use of automatic steerers is limited to relatively calm seas.

As mentioned, the simplest systems use a pair of push buttons. Each button operates the steering motor in a different direction. The primary advantage of these simple units is that they free the helmsman of the boredom of standing in one spot and allow him to move about.

The simplest of the automatic steerers are compass needle contact units, such as manufactured by Cowelco for about $600 complete. They operate through the steering wheel.

Slightly more elaborate is the Bendix Photo-electric Pilot which makes no physical contact with the compass needle, and can operate the steering motor as the result of as little as a half degree variation from the course. It retails for about $500.

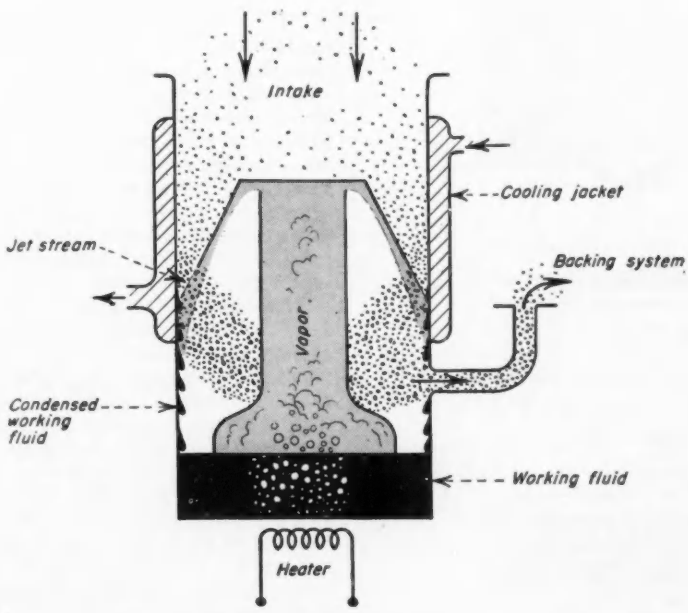
Probably one of the most complex and versatile systems is sold by The Navilog Co. for about $1600. The sensing element for this unit operates directly on the earth's lines of force. A servo unit keeps the sensing element pointed north. Rudder control proportional to deviation is another feature of this unit, making it practical for relatively rugged weather.

Nothing to It

From "Diffusion Pumps" by A. S. Darling. Published in "Mechanical World and Engineering Record," London. October, 1954.

The effective limit of mechanical oil-sealed pumps, for most industrial applications, is about 10^{-3} mm Hg. In this range vaporizing sealing oil and inevitable leaks cause pumping speeds to fall off rapidly.

Invented about the time of the World War I, the diffusion pump produces pressures in the range of 10^{-6} mm Hg on a commercial scale. In principle the pump is a trap for gas molecules that "diffuse" into it. A jet stream of mercury or oil vapor directed at an inward angle across the mouth of the pump knocks molecules that stray into the stream to the pump's center. The gas so collected is removed by one or a series of conventional pumps referred to as the "back-



Basic design of the diffusion pump

ing" system. The working fluid, which was used as vapor in the jet stream, is condensed upon striking the walls of the diffusion pump before it can be withdrawn by the backing system. Because the speed of molecular motion, and hence diffusion of gas into the pump, is independent of pressure, this factor does not influence the rate at which the diffusion pump operates. A heating element boils the working fluid to produce the pressure needed for the vapor stream. No pumping takes place until a threshold vapor stream velocity is reached. As the temperature of the heating element is increased the pumping speed rises sharply to a peak value, and then rapidly falls. The threshold backing pressure, however, continues to rise with the temperature of the heating element because vapors of the working fluid are being drawn into the backing system instead of condensing.

Ultimate (intake) pressures of 10^{-6} mm Hg may be obtained with single stage backing pumps using backing pressures of .05 mm Hg. Multistage diffusion pumps, containing a series of jets, operate on backing pressures of .3 mm Hg, creating pressure differentials of 300,000:1 between input and backing system.

Prognosticating TV

From "Redundancy in Television" by E. R. Kretzmer, Television Research, Bell Laboratories. "Bell Laboratories Record," Nov. 1954

Information, whether in pictorial or other forms, is rarely conveyed in the most efficient way possible. It is generally accompanied by so-called redundancy, which has been receiving increasing attention from communication engineers. In its simplest form, redundancy implies repetition that may be wasteful. However, it is valuable to the extent that it enhances reliability.

Redundancy appears in almost all communication signals. As a result of redundancy electrical communication systems require wider channels than might otherwise be necessary. The challenge to reduce redundancy has as its reward the possibility of greater economy in the use of communication facilities. The challenge —and reward—is particularly great in the case of cross-country television.

An example of redundancy in television: a scene involves the passage of an actor across a room. Unless the camera follows him, every object seen

on the screen except the man will be the same at the start of the sequence as at the end. Yet the complete scene will be produced 30 times a second, despite the fact that up to 90 per cent of the picture points will be identical for all the reproductions. The only information the observer requires continuously relates to the motions of the actor. Were there some method of "fixing" to the screen the stationary background and transmitting at an appropriate speed only those signals related to the man's motion, the result would not only be easier on the eyes but would require a fraction of the transmitting bandwidth. Even if the camera were to pan, some degree of prediction of change might be worked out.

ELECTRONIC IMPRESSIONISM

Current television techniques involve the transmission of 6,000,000 points per second. Through statistical techniques, engineers at Bell Laboratories are experimenting with anti-redundancy systems that will reduce transmission channel widths. One of their approaches to the problem runs along this line. A human observer can "make out" the meaning of an image even though many parts are missing. Why not devise a brain that would be built into a receiver to do the same thing, and a similar unit at the transmitter that would decide what could be safely omitted? Conceiving schemes of this sort, in principle, is easy enough; building them is another matter.

A circuit that has reached the model stage at Bell operates on this principle. A computer attempts to predict the brightness level of each point for an entire picture. But if the picture changes in some way, the predictions will err, and the computer can be made to measure the degree of error. The circuit measuring the error of prediction can then become the real transmitter to a receiver that is also equipped with a prognosticator. The only signals the receiver will pick up will be those indicating how much, and where, the transmitter's prophet is falling down, and consequently, how much the receiver's predictor is wrong. The picture on the screen is subsequently corrected. Carrying this idea a bit further, the predictor might be given enough memory to recognize cliché situations, and might be able to successfully guess the substance of the entire programs at their outset, receiving nothing from the transmitter but a few hints at the start.

NEW BOOKS

German Control Survey

REGELUNGSTECHNIK, Verein Deutcher Ingenieure und Verband Deutcher Elektrotechniker. $6\frac{1}{2}$ by $9\frac{3}{8}$ in., 280 pp. Published by Deutcher Ingenieur-Verlag Gmbh, (22a) Dusseldorf 10, Priz-Georg Str. 77/79, Germany. 24,—DM ($5.76)

Twenty-eight authorities have put their talents into this recent book from Germany. It is a survey of control engineering systems from steamrollers to steel mills. Originally presented as a series of professional-level lectures during 1953 and 1954 in Bonn and Essen, it gives a condensed explanation of control engineering's theory and mechanisms with a series of examples referring to a broad range of applications. An average of one illustration per page is maintained. The Introduction contains sections on The Meaning of Control Engineering for Technical Development, Control Engineering and Good Management, Fundamental Principles of Control Engineering, and Where Automatic Control Systems are Found.

The second chapter is titled "The Operation of Control Components," and has sections titled Mechanical Examples, Electrical Examples, Explanation of Mechanical Static Control, Explanation of Electrical Static Controls, Explanation of Two Position and Step Controls. Succeeding chapters are titled, "Control Systems and Automatic Controllers," "Application of Automatic Control in the Process Industries," "High Inertia Control," "Controlling Power Stations and Electrical Networks," and an Appendix listing 38 control engineering terms used in Germany, France, England, and America.

Robot Salesmen

AUTOMATIC SELLING. G. R. Schreiber, editor of Vend, 6 by $9\frac{1}{4}$ in., 195 pp. Published by John Wiley & Sons, Inc., 440 Fourth Avenue, N. Y. 16, N. Y. $5.00.

Robot retailers are selling goods worth $1.5 billion a year. At the present rate of growth, the figure will double within the next five years. The book outlines the rise of automatic selling, the automatic selling market, and the industry as the whole. If provides figures on the increase of different types of machines, what has been learned about locating them, and the economics of their operation.

Automatic retailing is a big field with a bigger future so that a book the size of this one can be contented

with describing the scope of present operations in moderately general terms. There is little or no mention of mechanism or design trends, beyond the observation that electrically powered machines, often incorporating heating or refrigerating elements, are on the increase. This book is aimed for a non-engineering audience, but discusses the foundations of the machine vending business in a way that might stimulate those thinking of data processing on a systems level, or process-systems engineers concerned with market variations. Example: one dairy sells its entire milk output by machine—one per cow, as a matter of fact—with sales highest on weekends.

Some interesting observations: customers prefer to push a button to start the delivery cycle, and are confused if the coin alone does the job; one of the headaches facing vending machine manufacturers today is the diversity of cabinet styles and the resultant conglomeration-effect when several are placed together. Some work has been done towards putting a battery of machines behind a single large panel, with only the control and delivery elements protruding. Perhaps a graphic control panel arrangement could conform to dietary lines?

Two significant trends in automatic retailers are making their appearance: the outdoor unit, which can be placed at the most convenient location with respect to market; and the multi-product machine, which embodies maximum versatility in its line of merchandise. Strictly a primer, and oriented along business interests, "Automatic Selling" attempts to provide basic information on the why's and how's of mechanical merchandising.

How to Organize Control

ENGINEERING CYBERNETICS. *H. S. Tsien, Daniel and Florence Guggenheim, Jet Propulsion Center, California Institute of Technology.* 6¼ by 9¼ in., 289 pp. Published by McGraw-Hill Book Company, Inc., 330 West 42nd Street, New York 36, N. Y. $6.50.

This book comprises a Preface, a well-detailed Table of Contents, 18 Chapters of theoretical context, and a fair Index. It is excellently-bound, superlatively-printed, and essentially without typographical errors. The author's exposition is clear, well-paced, concisely-phrased, and admirably ac-

NEW BOOKS

curate in statement. This last characteristic, conjoined with note of only a few errors during an intensive reading of the text, evidences the author's mastery of the subject matter encompassed in "Engineering Cybernetics."

The origin of the title and the purpose of the book are explained in the Preface. Thus, assuming "cybernetics . . . is the science of organization of mechanical and electrical components for stability and purposeful action," the author states "the purpose of 'Engineering Cybernetics' is then to study those parts of the broad science of cybernetics which have direct engineering applications in designing controlled or guided systems."

This "study" is effected in a wholly analytic fashion. However, the mathematics used is not difficult. A knowledge of the elements of ordinary differential equations, Fourier series, and integration in the complex plane will suffice most readers, since other mathematical technique is detailed as introduced.

The first four chapters are, briefly, a capsule presentation of certain basic aspects of elementary servomechanism theory. Thus, 1. "Introduction" (pages 1-6); 2. "Method of Laplace Transform" (7-11); 3. "Input, Output and Transfer Function" (12-33); and 4. "Feedback Servomechanism" (34-52). These chapters are well-written, although marred by use of the old KG(s) notation (with the usual consequence that no single, inclusive, unambiguous definition is advanced for the term "gain" or for calculation of K).

Chapter 5 comprises an excellent account of the theory of "Noninteracting Controls" (53-66), as originated by Boksenbom and Hood in 1950, supported by a detailed study of the control of a turbopropeller engine.

Chapter 6, on "alternating-current

FEEDBACK FANCY

Needed: A self-mounted stuffing gage which would tell the rotund eater when to stop.

Suggested: A preset strain-gage circuit, mounted neatly underneath the shirt to register abdominal tautness and start a warning buzzer in the pocket.

Motor Servomechanisms and Oscillating Control Servomechanisms" (70-82), is largely a reproduction of the context of Chapter IX of MacColl's well-known book, supported by additional material stemming from more recent papers by Lozier and Loeb. Likewise, Chapter 7 on "Sampling Servomechanisms" (83-93) largely parallels Chapter X of MacColl's book, thus details the use of starred transforms in the analysis of sampling servos through illustrative determination of the response of a simple, particular system. In virtue of its origin in MacColl's 1945 text, this chapter encompasses no account of the large volume of work done on sampling over the past decade (and particularly during the last several years).

Aside from Chapter 5, the essential contents of the above-mentioned chapters are readily available in earlier-published books. However, such is not true of most of the content of the succeeding chapters, and it is in these chapters that the essential novelty and merit of the book lies. Lack of space forestalls detailed discussion of their unique information and theory.

For the most part, the numerous illustrative problems which admirably buttress and exemplify the theory advanced stem for control problems associated with rocketry, aerodynamics, jet or internal combustion engines, or kindred fields indicative of the author's employment. However, this book can yet be read with profit, irrespective of the reader's particular control interest.

Many of the topics are only briefly treated (for example, those in "Nonlinear Systems"); other topics are not sufficiently up-to-date (for example, the treatment of "Sampling Servomechanisms"); no problems are advanced for use as student exercises; and other deficiencies relative to satisfactory classroom use could be cited.

This book is a text which can be read with profit by: (i) the graduate student, teacher, engineer, physicist or other party interested in automatic control theory who seeks a well-written introduction to one or more of the major topics discussed in the book, prior to detailed study of the original sources and resulting periodical literature to-date thereon; or (ii) by anyone interested in automatic control theory who desires a concisely-written overall-account of automatic control theory in the large, including account of certain powerful techniques of design and analysis that have as yet been only limitedly employed.

WHAT'S AHEAD: MEETINGS

JANUARY

Society of Automotive Engineers, (Golden Anniversary Annual Meeting), Sheraton-Cadillac Hotel and Hotel Statler, Detroit. Jan. 10-14

American Institute of Electrical Engineers and Institute of Radio Engineers (devoted to high-frequency measurements), Hotel Statler, Washington, D. C. Jan. 17-19

Texas A & M, Symposium on Instrumentation for the Process Industries, School of Engineering, Chemical Engineering Dept., College Station, Texas. Jan. 26-28

American Institute of Electrical Engineers (winter general meeting), Hotel Statler, New York, N. Y. Jan. 31-Feb. 4

FEBRUARY

Institute of Radio Engineers, Southwestern Convention, (session on servomechanisms and feedback control systems, Feb. 12), Baker Hotel, Dallas, Tex. Feb. 10-12

Instrument Society of America, New York Section, (session on instrumentation for data reduction and presentation), Hotel Statler, New York, N. Y. Feb. 23

MARCH

American Institute of Electrical Engineers, Institute of Radio Engineers, Association for Computing Machinery, Western Computer Conference, Hotel Statler, Los Angeles, Calif. Mar. 1-3

American Institute of Electrical Engineers, Utilization of Aluminum Conference, William Penn Hotel, Pittsburgh, Pa. Mar. 15-17

Institute of Radio Engineers, National Convention, Waldorf-Astoria and Kingsbridge Armory, New York, N. Y. Mar. 21-24

American Institute of Electrical Engineers, Materials Handling Conference, Hotel Cleveland, Cleveland, Ohio. Mar. 28-29

APRIL

American Institute of Electrical Engineers, Southern District Meeting, St. Petersburg, Fla. Apr. 13-15

MAY

American Institute of Electrical Engineers, Middle Eastern District Meeting, Columbus. May 4-6

American Institute of Electrical Engineers, Electric Heating Conference, LaSalle Hotel, Chicago. May 10-11

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articles

CONTROL ENGINEERING's December articles and articles appearing in this issue are available to CONTROL ENGINEERING subscribers. Articles in future issues will be available.

1954's EDITORIAL INDEX

CONTROL ENGINEERING's 1954 EDITORIAL INDEX covering Volume I is available to subscribers. The INDEX appears in this issue.

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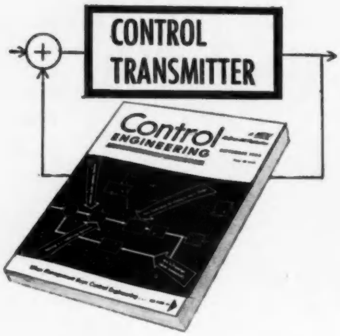

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New Ads Received by January 3rd at the New York office, 330 W. 42nd St., New York 36, N. Y., will appear in the February issue subject to limitations of space available.

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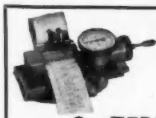

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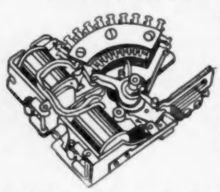

Mfg by Western Electric, Automatic Electric Sales Minor Switch 10 steps and off Single Level; Contacts: Gold plated brass; Bridging Wiper; Operating Voltage 6.0 to 12.0 V. DC Resistance: Oper. Coil 6 ohm; Reset Coil 9 ohm; Net Weight: 1 lb; W.E. Type SS5 #R960..11.95
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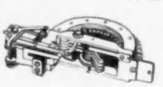

Mfg. by Western Electric Co., Automatic Electric Sales; 22 step; 5 levels; Bridging Wipers; Contacts: Gold plated brass; Operating Voltage: 5.5 to 12 V. DC; Coil Resistance: 4.0 ohm; Interrupter Switch: 1 Break-Make; Net Weight: 2 lb. 2 oz. SS6 #R926 14.75
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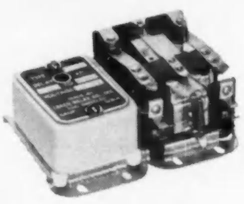

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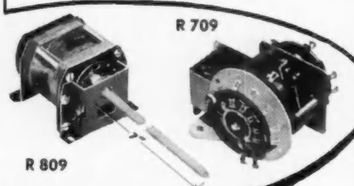

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The "CONTROL TRANSMITTER" serves as an active market place for buying and selling used and surplus elements and components of control systems. It will be consulted regularly by prospective buyers of such equipment offered by individual plants or dealers.

If you have used or surplus elements and components of control systems lying around idle in your plant, you can help other readers of the "CONTROL TRANSMITTER" who need such equipment by bringing it to their attention.

You may find bargains in hard-to-get components through the dealers advertising in this section. Make the reading of "CONTROL TRANSMITTER" a monthly habit.

Capital Spending Plans for 1955 . . .

Here is Good News About Business Prospects

In 1955, American industry is now planning to spend within 5 per cent of the amount it is spending this year on new plant and equipment. This is the tensely awaited result of a check-up just completed by the McGraw-Hill Department of Economics.

Hundreds of companies, by far the largest number in the eight-year history of these McGraw-Hill surveys, cooperated in the check-up. Combined, they represent 29 per cent of all industrial employment and over 60 per cent of employment in the industries where capital investment is highest. Such a broad cross section constitutes a reliable gauge of the plans of industry as a whole.

PLANS FOR CAPITAL INVESTMENT

	MILLIONS OF DOLLARS			Percent Change
	1953 ACTUAL*	1954 ESTIMATED*	1955 PLANNED	1954-1955
All Manufacturing	$10,026	$ 9,249	$ 8,598	—7%
Petroleum Industry†	4,600	4,875	4,920	+1
Mining	506	380	311	—18
Railroads	1,312	851	769	—10
Other Transportation and Communications	2,954	2,922	2,640	—10
Electric and Gas Utilities	4,548	4,274	4,206	—2
ALL INDUSTRY	23,271	21,784	20,727	—5

*United States Department of Commerce; Chase National Bank; McGraw-Hill Department of Economics

†Petroleum refining, included under both "All Manufacturing" and "Petroleum Industry," is included only once in the total

What is the meaning of these plans, detailed by the table below, for capital investment next year? Is it good or bad news, so far as it concerns the prospect of continuing prosperity? It is to this crucial question that this editorial is addressed.

Key to Prosperity

It is not only good but very important business news that American industry plans to spend in 1955 almost as much for new plant and equipment as it is spending this year. The reason it is important is that a high level of activity in the capital goods industries is universally recognized as a particularly potent ingredient of prosperity for the nation as a whole. A dollar spent for capital goods is spent again and again for wages and materials. Its stimulating effects, called by economists multiplying effects, move through the economy in much the same way that a pebble tossed into a pond creates a widening circle of ripples. This is one reason why there is such intense business interest in the surveys of plans for capital investment.

Here are the principal reasons why the results of the McGraw-Hill survey are a good omen for continuing prosperity:

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1. American industry is demonstrating that it does not need the stimulus of war-created shortages, or a rearmament boom, in order to maintain a very high level of capital investment.

The slight decrease now planned for 1955 will still maintain a level only about 11 percent below the all-time peak attained in 1953 under the stimulus of a defense expansion boom.

2. Capital investment promises not merely to stabilize at a high level, but actually to increase as 1955 goes on and thus give renewed stimulus to business.

The level of investment now planned for 1955 by *industry* — manufacturing, petroleum, mining, transportation, communications and utilities — is within 5 per cent of 1954. Contract awards for *commercial* construction — stores, office buildings, warehouses and other service establishments — as compiled by the McGraw-Hill publication ENGINEERING NEWS-RECORD, indicate a substantial increase in 1955. Thus total capital expenditures by *all business* may be very close to this year's total.

Actually, in the fourth quarter of 1954, business capital expenditures, as reported to the U. S. Department of Commerce, are down about 2.5 per cent from the average for the year as a whole. So there is a good chance that during 1955 the annual rate of capital investment will rise above this present level.

Effect of Tax Changes

The plans reported by the McGraw-Hill survey are preliminary plans, reported at the beginning of the period of business budgeting for 1955. As budgets are completed, new projects may bring the total expenditure that is planned even closer to this year's figure and thus make an even greater contribution to continuing prosperity.

But it also cannot be too strongly emphasized that these are plans; they are not accomplished investments. As such they have the vulnerability to changed conditions that characterize any plans.

There is some indication in the results of the McGraw-Hill check-up that one change in conditions recently made by the United States government has had an important stimulating effect on plans for business investment next year. It is a liberalization of the allowances for depreciation. Apparently encouraged by this provision, most of the smaller companies are planning to maintain or increase their purchases of new equipment next year, whereas during the past three years their expenditures have been declining. This is obviously a development that strengthens our economy.

A government insensitive to the key importance of capital investment by business, both in providing prosperity and in raising our standard of living, might easily destroy the present plans. One of the easiest and surest means to do this is excessive taxation of business profits which are the key ingredient of business investment. Whether the extraordinarily constructive program recently enacted by the federal government in the field of business taxation can be sustained remains to be seen. **If it can be sustained, the remarkably cheering plans of business for capital investment in 1955 can readily become firm foundations for a continuing prosperity.**

This message is one of a series prepared by the McGraw-Hill Department of Economics to help increase public knowledge and understanding of important nationwide developments that are of particular concern to the business and professional community served by our industrial and technical publications.

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Donald C McGraw

PRESIDENT

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